

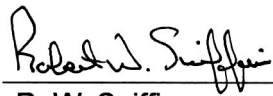
DSMS Telecommunications Link
Design Handbook

301, Rev. A

Coverage and Geometry

April 16, 2003

Document Owner:

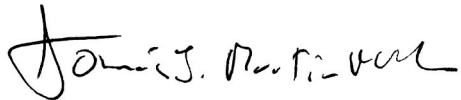


R. W. Sniffin

11/27/02

Date

Approved by:

 4/18/03

T. J. Martin Mur
Navigation Service Systems
Development Engineer

Date

Released by:

☐ Signature on File
☐ at DSMS Library

5/30/03

DSMS Document Release

Date

Change Log

Rev	Issue Date	Affected Paragraphs	Change Summary
Initial	11/30/2000	All	New Module
A	4/15/2003	2.1.1, 2.1.4, 2.2.3, 3.	Identified 11-m subnet as non-operational. Corrected equations 4, and 7. Added DSS 55. Documented improved coverage for MDSCC antennas. Expressed Geodetic coordinates in terms of WGS84 ellipsoid. Revised Proposed Capabilities.

Note to Readers

There are two sets of document histories in the 810-005 document that are reflected in the header at the top of the page. First, the overall document is periodically released as a revision when major changes affect a majority of the modules. For example, this document is part of Revision E. Second, the individual modules also change, starting as the initial issue that has no revision letter. When a module is changed, a change letter is appended to the module number on the second line of the header and a summary of the changes is entered in the module's change log.

Contents

<u>Paragraph</u>	<u>Page</u>
1 Introduction	6
1.1 Purpose.....	6
1.2 Scope	6
2 General Information	6
2.1 Station Locations	6
2.1.1 Antenna Reference Point	6
2.1.2 IERS Terrestrial Reference Frame.....	8
2.1.2.1 ITRF Cartesian Coordinates.....	9
2.1.2.2 ITRF Site Velocities.....	9
2.1.3 Geodetic Coordinates.....	9
2.1.4 Geocentric Coordinates.....	13
2.2 Coverage and Mutual Visibility.....	16
2.2.1 Use of Transmitters Below Designated Elevation Limits	16
2.2.1.1 Spacecraft Emergencies	16
2.2.1.2 Critical Mission Support	16
2.2.2 Mechanical Limits on Surveillance Visibility	16
2.2.2.1 Azimuth-Elevation Antennas	17
2.2.2.2 X-Y Antennas.....	17
2.2.2.3 Tilt-Azimuth-Elevation Antennas	17
2.2.3 Coverage Charts.....	17
2.2.3.1 70-m Subnet Receive Coverage of Planetary Spacecraft.....	17
2.2.3.2 70-m Subnet Transmit Coverage of Planetary Spacecraft	18
2.2.3.3 34-m HEF Subnet Receive Coverage of Planetary Spacecraft	18
2.2.3.4 34-m HEF Subnet Transmit Coverage of Planetary Spacecraft.....	18
2.2.3.5 34-m BWG Antennas Receive Coverage of Planetary Spacecraft	19
2.2.3.6 34-m BWG Antennas Transmit Coverage of Planetary Spacecraft	19
2.2.3.7 26-m Subnet Receive Coverage of Earth Orbiter Spacecraft.....	19
2.2.3.8 26-m Subnet Transmit Coverage of Earth Orbiter Spacecraft	19
2.2.3.9 34-m BWG Antennas Receive Coverage of Earth Orbiter Spacecraft	19
2.2.3.10 34-m BWG Antennas Receive Coverage of Earth Orbiter Spacecraft	19
2.2.4 Horizon Masks and Antenna Limits	20

<u>Paragraph</u>	<u>Page</u>
3 Proposed Capabilities.....	20
3.1 DSS 55 Implementation.....	20
3.2 DSS 65 Relocation.....	20
Appendix A References	47

Illustrations

<u>Figure</u>	<u>Page</u>
1. ITRF Cartesian and Geocentric Coordinate System Relationships.....	10
2. DSN 70-m Subnet Receive Coverage, Planetary Spacecraft.	21
3. DSN 70-m Subnet Transmit Coverage, Planetary Spacecraft.....	22
4. DSN 34-m HEF Subnet Receive Coverage, Planetary Spacecraft.....	23
5. DSN 34-m Subnet Transmit Coverage, Planetary Spacecraft.....	24
6. DSN 34-m BWG Antenna Receive Coverage, Planetary Spacecraft.	25
7. DSN 34-m BWG Antennas Transmit Coverage, Planetary Spacecraft.	26
8. DSN 26-m Subnet Receive Coverage, Earth Orbiter Spacecraft.	27
9. DSN 26-m Subnet Transmit Coverage, Earth Orbiter Spacecraft.....	28
10. DSN 34-m BWG Antennas Receive Coverage, Earth Orbiter Spacecraft.....	29
11. DSN 34-m BWG Antennas Transmit Coverage, Earth-Orbiter Spacecraft.....	30
12. DSS 14 Hour-Angle and Declination Profiles and Horizon Mask.....	31
13. DSS 15 Hour-Angle and Declination Profiles and Horizon Mask.	32
14. DSS 16 X-Y Profiles and Horizon Mask.	33
15. DSS 24 Hour-Angle and Declination Profiles and Horizon Mask.....	34
16. DSS 25 Hour-Angle and Declination Profiles and Horizon Mask.....	35
17. DSS 26 Hour-Angle and Declination Profiles and Horizon Mask.....	36
18. DSS 27 Hour Angle and Declination Profiles and Horizon Mask.....	37
19. DSS 34 Hour-Angle and Declination Profiles and Horizon Mask.....	38
20. DSS 43 Hour-Angle and Declination Profiles and Horizon Mask.....	39
21. DSS 45 Hour-Angle and Declination Profiles and Horizon Mask.....	40
22. DSS 46 X-Y Profiles and Horizon Mask.	41

<u>Figure</u>	<u>Page</u>
23. DSS 54 Hour-Angle and Declination Profiles and Horizon Mask.	42
24. DSS 55 Hour-Angle and Declination Profiles and Horizon Mask.	43
25. DSS 63 Hour-Angle and Declination Profiles and Horizon Mask.	44
26. DSS 65 Hour-Angle and Declination Profiles and Horizon Mask.	45
27. DSS 66 X-Y Profiles and Horizon Mask.....	46

Tables

<u>Table</u>	<u>Page</u>
1. DSN Antenna Types.....	7
2. ITRF93 Cartesian Coordinates for DSN Stations, Epoch 1993.0.....	11
3. ITRF93 Site Velocities for DSN Stations.....	12
4. Average Geoidal Separations at the DSN Complexes	12
5. Geodetic Coordinates for DSN Stations With Respect to the WGS84 Ellipsoid	14
6. Geocentric Coordinates for DSN Stations.....	15
7. Approximate Cable Wrap Limits for Azimuth-Elevation Antennas.....	18

1 Introduction

1.1 Purpose

This module describes the geometry and surveillance visibility provided by the DSN for support of spacecraft telecommunications.

1.2 Scope

This module provides the Deep Space Network (DSN) station coordinates that are required for spacecraft navigation and to locate the stations with respect to other points on the Earth's surface. Coverage charts are provided to illustrate areas of coverage and non-coverage from selected combinations of stations for spacecraft at selected altitudes. Horizon masks are included so the effects of terrain masking can be anticipated.

2 General Information

2.1 Station Locations

The following paragraphs discuss the important concepts relating to establishing the location of the DSN antennas.

2.1.1 Antenna Reference Point

The coordinates provided by this module refer to a specific point on each antenna. For antennas where the axes intersect, the reference point is the intersection of the axes. For antennas for which the axes do not intersect, the reference point is the intersection of the primary (lower) axis with a plane, perpendicular to the primary axis, and containing the secondary (upper) axis. Table 1 lists the DSN antennas by type and provides the axis offset where appropriate. The effect of this offset is to cause the range observable to be a function of antenna position as discussed in module 203 of this handbook.

Although the antenna reference point is fixed, the path length between this point and a spacecraft increases as the antenna elevation is changed from zenith to the horizon. This results from the antenna subreflector being moved to provide maximum gain as gravity distorts the antenna geometry. The effect can be modeled as a decrease in antenna height for orbit determination purposes. The effect is greatest on the 70-m antennas and is discussed in the appropriate Telecommunications Interface modules of this handbook.

Table 1. DSN Antenna Types

Antenna Type	Station Identifiers	Primary and Secondary Axes	Axis Offset
70-m	14, 43, 63	Az/EI	0
34-m High Efficiency (HEF)	15, 45, 65	Az/EI	0
34-m Beam Waveguide (BWG)	24, 25, 26, 34, 54, 55†	Az/EI	0
34-m High-speed Beam Waveguide (HSB)	27, 28†	Az/EI	1.83 m
26-m	16, 46, 66	X/Y	6.706 m
11-m OVLBI	23, 33, 53†	Tilt/Az/EI	0.391 m
<p>Az/EI Antenna's azimuth plane is tangent to the Earth's surface, and antenna at 90-degrees elevation is pointing at zenith.</p> <p>X/Y Primary axis (X) is aligned horizontally in an east-west (26-m antennas) or north-south (9-m antenna) direction. Secondary axis is aligned vertically in a north-south (26-m antennas) or east-west (9-m antenna) plane.</p> <p>Tilt/Az/EI The azimuth axis of the Az/EI mount is tilted to avoid an overhead keyhole. The direction of tilt is fixed for each pass and results in an apparent shift in the actual station location from the specified station location.</p> <p>† DSSs 23, 28, 33, and 53 are not presently in service. DSS 55 is under construction.</p>			

The 11-m antennas are unique in that the azimuth axis is tilted from the local vertical by a 7-degree wedge that is rotated to a position with respect to north called the "train angle" before the start of each track. This causes the station location to be displaced away from the train angle along a circular path having a radius equal to the axis offset. The vector ($\Delta \mathbf{r}_b$), which must be added to the station coordinates to compensate for this effect, can be derived from the train angle that is supplied to the user as part of the tracking data (see module 302) and the north and east station vectors (\mathbf{N} and \mathbf{E}) which are functions of the station geodetic coordinates.

$$\Delta \mathbf{r}_b = 0.391 \cos \theta \mathbf{N} + 0.391 \sin \theta \mathbf{E} \quad (1)$$

where:

λ = the train angle

$$\mathbf{N} = \begin{bmatrix} \sin \lambda_g \cos \lambda \\ \sin \lambda_g \sin \lambda \\ \cos \lambda_g \end{bmatrix} \quad (2)$$

$$\mathbf{E} = \begin{bmatrix} \sin \lambda \\ \cos \lambda \\ 0 \end{bmatrix} \quad (3)$$

λ_g = Station Geodetic Latitude (Table 5)

λ = Station Longitude

2.1.2 *IERS Terrestrial Reference Frame*

To use station locations with sub-meter accuracy, it is necessary to clearly define a coordinate system that is global in scope as opposed to the regional coordinate systems referenced in previous editions of this document. The International Earth Rotation Service (IERS) has been correlating station locations from many different services and has established a coordinate frame known as the IERS Terrestrial Reference Frame (ITRF). The IERS also maintains a celestial coordinate system and coordinates delivery of Earth-orientation measurements that describe the motion of station locations in inertial space. The DSN has adopted the IERS terrestrial system to permit its users to have station locations consistent with widely available Earth-orientation information.

The IERS issues a new list of nominal station locations each year, and these locations are accurate at the few-cm level. At this level of accuracy, one must account for ongoing tectonic plate motion (continental drift), as well as other forms of crustal motion. For this reason ITRF position coordinates are considered valid for a specified epoch date, and one must apply appropriate velocities to estimate position coordinates for any other date. Relative to the ITRF, even points located on the stable part of the North American plate move continuously at a rate of about 2.5 cm/yr.

The coordinates in this module are based on the 1993 realization of the ITRF, namely ITRF93, documented in IERS Technical Note 18 ⁽¹⁾. ITRF93 was different from earlier realizations of the ITRF in that it was defined to be consistent with the Earth Orientation Parameters (EOP) distributed through January 1, 1997. Earlier realizations of the ITRF were known to be inconsistent (at the 1-3 cm level) with the Earth orientation distributions.

After ITRF93 was published, the IERS decided to improve the accuracy of the EOP series and make it consistent with the ITRF effective January 1, 1997. This date was chosen because it enabled a defect in the definition of universal time to be removed at a time when its contribution was zero. In anticipation of this change, ITRF94 and ITRF95 were made consistent with the pre-ITRF93 definition of the terrestrial reference frame, and all prior EOP series were recomputed in accordance with the new system.

Until this change is fully adopted by the Earth-orientation community, the DSN is delivering Earth-orientation calibrations to navigation teams that are consistent with the earlier definition and using the ITRF93 reference frame. Users interested in precise comparison with other system should keep in mind the small systematic differences.

2.1.2.1 ITRF Cartesian Coordinates

Figure 1 illustrates the relationship between the ITRF Cartesian coordinates and geocentric coordinates discussed below. The Cartesian coordinates of the DSN station locations are fits to many years of tracking and Very-Long Baseline Interferometry data and are expressed in the ITRF93 reference system in Table 2. Table 2 also gives the characteristic position uncertainty for horizontal and vertical components.

2.1.2.2 ITRF Site Velocities

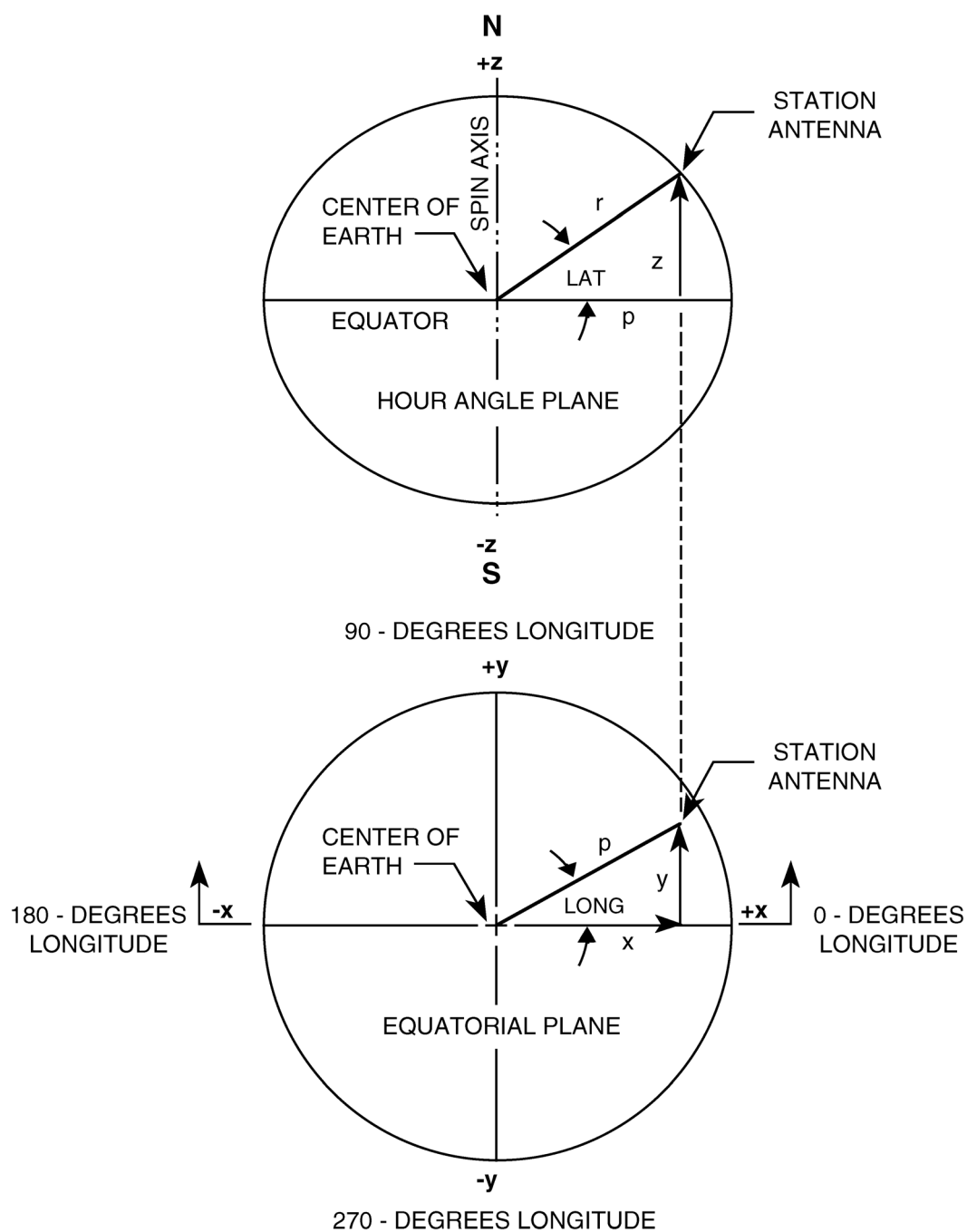
The locations given in Table 2 are for the epoch 1993.0. To transform these locations to any other epoch, the site velocities should be used. Table 3 gives the ITRF93 site velocities for the DSN stations, in both Cartesian (x, y, z) and east-north-vertical (e, n, v) components.

2.1.3 Geodetic Coordinates

Locations on the Earth's surface are defined with respect to the geoid. That is, the surface around or within the Earth that is normal to the direction of gravity at all points and coincides with mean sea level (MSL) in the oceans. The geoid is not a regular surface because of variations in the Earth's gravitational force. To avoid having to make computations with respect to this non-mathematical surface, computations are made with respect to an ellipsoid, that is, the surface created by rotating an ellipse around one of its two axes. The ellipsoid is uniquely defined by specifying the equatorial radius and the flattening (that is, the amount that the ellipsoid deviates from a perfect sphere). The relationship between the polar and equatorial axes is given by the following expression:

$$(\text{polar axis}) = (\text{equatorial axis}) \left[1 \mp 1/\text{flattening} \right] \quad (4)$$

In the past, the ellipsoid used was chosen to be a best fit to the geoid in the area of interest. However, the presence of the Global Positioning Satellite (GPS) system has resulted in a single ellipsoid, named the WGS 84 Ellipsoid, being adopted for most geodetic measurements. This ellipsoid, while providing a good fit to the entire Earth, results in larger differences between the geoid and the ellipsoid than could be obtained when ellipsoids were chosen to fit only a



Z = Height above (+z) or below (-z) equatorial plane.
Y = Distance in front of (+y) or behind (-y) plane (Hour Angle plane) established by spin axis and Greenwich meridian.
X = Distance from spin axis towards Greenwich meridian (+x) or towards 180-degree meridian (-x).

Figure 1. ITRF Cartesian and Geocentric Coordinate System Relationships

Table 2. ITRF93 Cartesian Coordinates for DSN Stations, Epoch 1993.0

Antenna		Cartesian Coordinates			Uncertainty	
Name	Description	x(m)	y(m)	z(m)	h(m)	v(m)
DSS 13	34-m R & D	□2351112.491	□4655530.714	+3660912.787	0.04	0.05
DSS 14	70-m	□2353621.251	□4641341.542	+3677052.370	0.03	0.03
DSS 15	34-m HEF	□2353538.790	□4641649.507	+3676670.043	0.03	0.03
DSS 16	26-m X-Y	□2354763.158	□4646787.462	+3669387.069	0.05	0.10
DSS 23 ³	11-m Tilt/Az/EI	□2354757.567	□4646934.675	+3669207.824	0.05	0.10
DSS 24	34-m BWG	□2354906.528	□4646840.114	+3669242.295	0.05	0.10
DSS 25	34-m BWG	□2355021.795	□4646953.325	+3669040.628	0.05	0.10
DSS 26	34-m BWG	□2354890.967	□4647166.925	+3668872.212	0.05	0.10
DSS 27	34-m HSB	□2349915.260	□4656756.484	+3660096.529	0.05	0.10
DSS 28 ³	34-m HSB	-2350101.849	□4656673.447	+3660103.577	0.05	0.10
DSS 33 ³	11□m Tilt/Az/EI	□4461083.514	+2682281.745	□3674570.392	0.03	0.10
DSS 34	34-m BWG	□4461146.720	+2682439.296	□3674393.517	0.05	0.10
DSS 43	70-m	□4460894.585	+2682361.554	□3674748.580	0.03	0.03
DSS 45	34-m HEF	□4460935.250	+2682765.710	□3674381.402	0.03	0.03
DSS 46	26-m X-Y	□4460828.619	+2682129.556	□3674975.508	0.04	0.04
DSS 53 ³	11-m Tilt/Az/EI	+4849330.129	□0360338.092	+4114758.766	0.05	0.10
DSS 54	34-m BWG	+4849434.496	□0360724.062	+4114618.570	0.05	0.10
DSS 55 ³	34-m BWG	+4849525.320	-0360606.299	+4114494.905	0.05	0.10
DSS 63	70-m	+4849092.647	□0360180.569	+4115109.113	0.03	0.03
DSS 65	34-m HEF	+4849336.730	□0360488.859	+4114748.775	0.03	0.03
DSS 66	26-m X-Y	+4849148.543	□0360474.842	+4114995.021	0.05	0.10
Notes: 1. All antennas are AZ-EL type unless otherwise specified. 2. Horizontal (h) and vertical (v) uncertainties are 1-sigma. 3. DSSs 23, 28, 33, and 53 are not presently in service. DSS 55 is under construction.						

Table 3. ITRF93 Site Velocities for DSN Stations

Complex	x(m/yr)	y(m/yr)	z(m/yr)	e(m/yr)	n(m/yr)	v(m/yr)
Goldstone (Stations 1x & 2x)	-0.0191	0.0061	-0.0047	-0.0198	-0.0057	-0.0001
Canberra (Stations 3x & 4x)	-0.0354	-0.0017	0.0412	0.0197	0.0506	0.0001
Madrid (Stations 5x & 6x)	-0.0141	0.0222	0.0201	0.0211	0.0255	0.0011

portion of the Earth. This difference, the *Geoidal Separation*, must be subtracted from the WGS 84 height measurements to give the height with respect to mean sea level.

Geoidal separations are typically determined from satellite altimetry and gravity measurements and maintained as a grid of points in longitude and latitude. Modern GPS equipment uses a sixteen point interpolation routine to estimate the surface curvature in the grid-square of interest and the geoidal separation at the specific point within the grid-square. Table 4 provides the average geoidal separation for the three DSN complexes. These numbers do not take into consideration such things as topography within the complex and grading that was done when the antennas were installed.

Table 4. Average Geoidal Separations for the DSN Complexes

Complex	Geoidal Separation(m)
Goldstone (Stations 1x & 2x)	-30.6
Canberra (Stations 3x & 4x)	19.3
Madrid (Stations 5x & 6x)	54.1

Once the Cartesian coordinates (x, y, z) are known, they can be transformed to geodetic coordinates in longitude, latitude, and height (λ , ϕ , h) with respect to the ellipsoid by the following non-iterative method (Reference 2):

$$\varphi = \tan^{-1} \frac{y}{x} \quad (5)$$

$$\varphi = \tan^{-1} \frac{z(1-f) + e^2 a \sin^3 \varphi}{(1-f)(p - e^2 a \cos^3 \varphi)} \quad (6)$$

$$h = p \cos \varphi + z \sin \varphi a \left(1 - e^2 \sin^2 \varphi\right)^{\frac{1}{2}} \quad (7)$$

where:

$$f = \frac{1}{\text{flattening}} \quad (8)$$

$$e^2 = 2f - f^2 \quad (9)$$

$$p = \left(x^2 + y^2\right)^{\frac{1}{2}} \quad (10)$$

$$r = \left(p^2 + z^2\right)^{\frac{1}{2}} \quad (11)$$

$$\varphi = \tan^{-1} \frac{z}{p} (1-f) + \frac{e^2 a}{r} \quad (12)$$

Table 5 provides geodetic coordinates derived by the preceding approach using the WGS84 ellipsoid that has a semi-major axis (a) of 6378137 m and a flattening of 298.2572236.

2.1.4 Geocentric Coordinates

Geocentric coordinates (also referred to as cylindrical coordinates) are used by navigation analysts when corrections to station locations are being investigated. They relate the station location to the Earth's center of mass in terms of the geocentric radius and the angles between the station and the equatorial and hour angle planes. Geocentric coordinates for the DSN stations are provided in Table 6.

Table 5. Geodetic Coordinates for DSN Stations With Respect to the WGS 84 Ellipsoid

Antenna		latitude (ϕ)			longitude (λ)			height(h) ³
Name	Description	deg	min	sec	deg	min	sec	(m)
DSS 13	34-m R & D	35	14	49.79299	243	12	19.95492	1070.474
DSS 14	70-m	35	25	33.24476	243	6	37.66967	1001.409
DSS 15	34-m HEF	35	25	18.67347	243	6	46.10495	973.240
DSS 16	26-m X-Y	35	20	29.54348	243	7	34.86823	944.006
DSS 23 ²	11-m Tilt/Az/El	35	20	22.38293	243	7	37.70043	945.380
DSS 24	34-m BWG	35	20	23.61450	243	7	30.74700	951.440
DSS 25	34-m BWG	35	20	15.40452	243	7	28.70236	959.676
DSS 26	34-m BWG	35	20	8.48171	243	7	37.14556	969.454
DSS 27	34-m HSB	35	14	17.78010	243	13	24.06569	1052.498
DSS 28 ²	34-m HSB	35	14	17.78094	243	13	15.99910	1064.677
DSS 33 ²	11-m Tilt/Az/El	-35	24	1.76096	148	58	59.12203	684.134
DSS 34	34-m BWG	-35	23	54.53942	148	58	55.06235	692.006
DSS 43	70-m	-35	24	8.74345	148	58	52.55394	688.903
DSS 45	34-m HEF	-35	23	54.46357	148	58	39.65991	674.381
DSS 46	26-m X-Y	-35	24	18.05420	148	58	59.08570	676.846
DSS 53 ²	11-m Tilt/Az/El	40	25	38.47992	355	45	1.24306	826.795
DSS 54	34-m BWG	40	25	32.23108	355	44	45.24458	836.895
DSS 55 ²	34-m BWG	40	25	27.45921	355	44	50.51161	819.003
DSS 63	70-m	40	25	52.34864	355	45	7.16030	864.838
DSS 65	34-m HEF	40	25	37.86011	355	44	54.88622	833.833
DSS 66	26-m X-Y	40	25	47.90322	355	44	54.88739	849.876
Notes:								
1. All antennas are AZ-EL type unless otherwise specified.								
2. DSSs 23, 28, 33, and 53 are not presently in service. DSS 55 is under construction.								
3. Geoidal separation must be subtracted from WGS 84 height to get MSL height.								

Table 6. Geocentric Coordinates for DSN Stations

Antenna		Geocentric Coordinates			
Name	Description	Spin Radius (m)	Latitude (deg)	Longitude (deg)	Geocentric Radius (m)
DSS 13	34-m R & D	5215524.535	35.0660185	243.2055430	6372125.125
DSS 14	70-m	5203996.955	35.2443527	243.1104638	6371993.286
DSS 15	34-m HEF	5204234.332	35.2403133	243.1128069	6371966.540
DSS 16	26-m X-Y	5209370.715	35.1601777	243.1263523	6371965.530
DSS 23 ²	11-m Tilt/Az/El	5209499.503	35.1581932	243.1271390	6371967.603
DSS 24	34-m BWG	5209482.489	35.1585347	243.1252075	6371973.542
DSS 25	34-m BWG	5209635.578	35.1562595	243.1246395	6371982.579
DSS 26	34-m BWG	5209766.971	35.1543411	243.1269849	6371993.032
DSS 27	34-m HSB	5216079.244	35.0571456	243.2233516	6372110.269
DSS 28 ²	34-m HSB	5216089.176	35.0571462	243.2211109	6372122.448
DSS 33 ²	11-m Tilt/Az/El	5205372.367	-35.2189880	148.9830895	6371684.945
DSS 34	34-m BWG	5205507.750	-35.2169868	148.9819620	6371693.561
DSS 43	70-m	5205251.579	-35.2209234	148.9812650	6371689.033
DSS 45	34-m HEF	5205494.708	-35.2169652	148.9776833	6371675.906
DSS 46	26-m X-Y	5205075.496	-35.2235036	148.9830794	6371676.067
DSS 53 ²	11-m Tilt/Az/El	4862699.481	40.2375043	355.7503453	6370014.595
DSS 54	34-m BWG	4862832.239	40.2357708	355.7459008	6370025.429
DSS 55 ²	34-m BWG	4862914.015	40.2344461	355.7473643	6370007.931
DSS 63	70-m	4862450.981	40.2413536	355.7519890	6370051.221
DSS 65	34-m HEF	4862717.238	40.2373325	355.7485795	6370021.697
DSS 66	26-m X-Y	4862528.530	40.2401197	355.7485798	6370036.713
Notes:					
1. All antennas are AZ-EL type unless otherwise specified.					
2. DSSs 23, 28, 33, and 53 are not presently in service. DSS 55 is under construction.					

2.2 *Coverage and Mutual Visibility*

The coverage and mutual visibility provided for spacecraft tracking depends on the altitude of the spacecraft, the type or types of antennas being used, the blockage of the antenna beam by the landmask and structures in the immediate vicinity of the antennas, and whether simultaneous uplink coverage is required. Receive limits are governed by the mechanical capabilities of the antennas and the terrain mask. Transmitter limits, on the other hand, are based on radiation hazard considerations to on-site personnel and the general public and are set above the terrain mask and the antenna mechanical limits.

2.2.1 *Use of Transmitters Below Designated Elevation Limits*

Requests for coordination to relinquish the transmitter radiation restrictions will be considered for spacecraft emergency conditions or for critical mission support requirements (conditions where low elevation or high-power transmitter radiation is critical to mission objectives). In either event, the uplink radiation power should be selected as the minimum needed for reliable spacecraft support.

2.2.1.1 *Spacecraft Emergencies*

The need for violation of transmitter radiation restrictions to support a spacecraft emergency will be determined by the DSN. The restrictions will be released after assuring that appropriate local authorities have been notified and precautions have been taken to ensure the safety of on-site personnel.

2.2.1.2 *Critical Mission Support*

If critical mission activities require the transmitter radiation restrictions to be violated, the project is responsible for notifying the DSN through their normal point of contact three months before the activity is scheduled. The request must include enough information to enable the DSN to support it before the appropriate authorities. Requests made less than three months in advance will be supported on a best-efforts basis and will have a lower probability of receiving permission to transmit. Requests will be accepted or denied a minimum of two weeks before the planned activity.

2.2.2 *Mechanical Limits on Surveillance Visibility*

All DSN antennas have areas of non-coverage caused by mechanical limits of the antennas. The first area is the mechanical elevation limit, which is approximately six degrees for antennas using an azimuth-elevation mount and somewhat lower for antennas with X-Y mounts. A second area of non-coverage is the area off the end or ends of the antenna's primary axis referred to as the *keyhole*.

2.2.2.1 *Azimuth-Elevation Antennas*

The keyhole of the DSN azimuth-elevation antennas is directly overhead and results from the fact that the antennas can only be moved over an arc of approximately 85 degrees in elevation. In order to track a spacecraft which is passing directly overhead, it is necessary to rotate the antenna 180 degrees in azimuth when the spacecraft is at zenith in order to continue the track. Thus, the size of the keyhole depends on how fast the antenna can be slewed in azimuth. Specifications on antenna motion are contained in module 302, Antenna Positioning. The location of the DSN antennas is such that overhead tracks are not required for spacecraft on normal planetary missions.

The DSN azimuth-elevation antennas have an additional restriction on antenna motion caused by the routing path of cables and hoses between the fixed and rotating portions of the antenna. This azimuth cable wrap has no effect on surveillance visibility but does place a restriction on the time between tracks due to the requirement to unwind the cables. Table 7 provides the approximate cable wrap limits for the DSN azimuth-elevation antennas.

2.2.2.2 *X-Y Antennas*

The DSN 26-m X-Y antennas (DSS 16, 46, and 66) have two keyholes caused by requirements for mechanical clearance in the antenna structure. The keyholes are located directly to the east and west of the 26-m antennas.

2.2.2.3 *Tilt-Azimuth-Elevation Antennas*

The DSN 11-m antennas (DSS 23, 33, and 53) have a keyhole above each antenna, which is offset from zenith by 7-degrees. The location of this keyhole is set before each pass to a position that will provide clearance between the keyhole and the scheduled track.

2.2.3 *Coverage Charts*

The following figures provide examples of coverage for various combinations of stations, spacecraft altitudes, and type of support. These figures were plotted by a program written as a collection of Microsoft Excel 97/98 macros. This program is available for download (1.7 Mbytes) from the 810-005 web site (<http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/>).

2.2.3.1 *70-m Subnet Receive Coverage of Planetary Spacecraft*

Figure 2 illustrates the receive coverage of planetary spacecraft by the DSN 70-m antenna subnet. The small ovals at each antenna location on the figure represent the 70-m antenna keyholes above each station and are approximately to scale.

Table 7. Approximate Cable Wrap Limits for Azimuth-Elevation Antennas

Antenna		Azimuth Position (Degrees)		
Name(s)	Description	Center of Wrap	CW Limit	CCW Limit
DSS 14, 63	70-m	45	310	140
DSS 43	70-m	135	40	230
DSS 15, 65	34-m HEF	135	360	270
DSS 45	34-m HEF	45	270	180
DSS 24, 25, 26, 54, 55	34-m BWG	135	360	270
DSS 34	34-m BWG	45	270	180
DSS 27	34-m HSB	135	360	270
DSS 23, 33, 53	11-m	0	380	(-) 380

2.2.3.2 70-m Subnet Transmit Coverage of Planetary Spacecraft

Figure 3 illustrates the transmit coverage of planetary spacecraft by the DSN 70-m antenna subnet using a 10.4-degree transmit elevation limit at DSS 14 and a 10.2-degree transmit elevation limit at DSS 43 and DSS 63. The small ovals at the antenna locations on the figure represent the 70-m antenna keyholes. The reduced coverage to the west of DSS 63 is caused by the need to have a 20.2-degree elevation limit to protect the high ground to the northwest of the station.

2.2.3.3 34-m HEF Subnet Receive Coverage of Planetary Spacecraft

Figure 4 illustrates the receive coverage of planetary spacecraft by the DSN 34-m HEF antenna subnet. The keyhole above each 34-m HEF antenna is very small and is somewhat exaggerated for clarity on the maps. This chart is very similar to Figure 2 but is included to show that the location of DSS 65 shifts the apparent position of the high ground to the north and west of where it is observed from DSS 63.

2.2.3.4 34-m HEF Subnet Transmit Coverage of Planetary Spacecraft

Figure 5 illustrates the transmit coverage of planetary spacecraft by the DSN 34-m HEF antenna subnet using a 10.6-degree transmit elevation limit at DSS 15, a 10.5-degree transmit limit at DSS 45, and a 10.3-degree limit at DSS 65. As is the case in Figure 4, the size of the circles used to indicate the keyholes on the map are larger than the actual size of the 34-m HEF antenna keyholes. Protection of the high ground at DSS 65 is provided by disabling the transmitter between 327.4 and 358.6 degrees azimuth.

2.2.3.5 *34-m BWG Antennas Receive Coverage of Planetary Spacecraft*

Figure 6 illustrates the receive coverage of planetary spacecraft by the DSN 34-m BWG antennas. As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes. This chart is very similar to Figures 2 and 4 but is included to show that the location of DSS 54 shifts the apparent position of the high ground to where it does not significantly affect tracking coverage.

2.2.3.6 *34-m BWG Antennas Transmit Coverage of Planetary Spacecraft*

Figure 7 illustrates the transmit coverage of planetary spacecraft by the DSN 34-m BWG antennas. As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes. Protection of the high ground at DSS 54 and DSS 55 is provided by placing a 13.6-degree lower elevation limit on the transmitter between 267 and 3 degrees azimuth.

2.2.3.7 *26-m Subnet Receive Coverage of Earth Orbiter Spacecraft*

Figure 8 illustrates the receive coverage of Earth-orbiter spacecraft at altitudes of 200 km, 1000 km, and 5000 km by the DSN 26-m antenna subnet. This chart can also be used when the 34-m HSB antenna, DSS 27, is substituted for the Goldstone 26-m antenna. DSS 27 is collocated with an inactive antenna, DSS 28, approximately 14.5 km southeast of DSS 16. The inactive antenna blocks reception to the west in the same place and approximately to the same extent as the west keyhole of DSS 16. DSS 27 also has a very small keyhole directly overhead.

2.2.3.8 *26-m Subnet Transmit Coverage of Earth Orbiter Spacecraft*

Figure 9 illustrates the transmit coverage of Earth-orbiter spacecraft at altitudes of 200 km, 1000 km, and 5000 km by the DSN 26-m antenna subnet. This chart is similar to Figure 8. However, the limits placed on transmitter operation in order to clear terrain and structures are clearly visible.

2.2.3.9 *34-m BWG Antennas Receive Coverage of Earth Orbiter Spacecraft*

Figure 10 illustrates the receive coverage of Earth-orbiter spacecraft by the DSN 34-m BWG antennas at altitudes of 500 km, 5000 km, and geosynchronous (35789 km). As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes

2.2.3.10 *34-m BWG Antennas Receive Coverage of Earth Orbiter Spacecraft*

Figure 11 illustrates the transmit coverage of Earth-orbiter spacecraft by the DSN 34-m BWG antennas. As is the case with the other 34-m antennas, the size of the keyhole circles on the map is larger than the actual size of the antenna keyholes. Protection of the high ground at DSS 54 and 55 is provided by a 13.6-degree lower elevation limit between 267 and 3 degrees azimuth.

2.2.4 *Horizon Masks and Antenna Limits*

Figures 12 through 30 show the horizon mask and transmitter limits for all DSN stations. The transmitter limits are identified as the L/P (low power) transmitter mask (or the H/P (high power) transmitter mask depending on the type of transmitter that is available. Only the 70-m stations have both L/P and H/P transmitters and DSS 43 is the only station that uses different H/P and L/P transmitter limits. At DSS 43, the H/P transmitter limit is set at 10.4 degrees whereas the L/P transmitter limit is set at 10.2 degrees. DSS 14 uses a 10.4-degree limit for both transmitters and DSS 63 uses a 10.2-degree limit except to the northwest of the station where it is set to 20.2 degrees. These masks and limits are the ones used to establish the coverage depicted in Figures 2 through 11. Each chart shows antenna coordinates in two coordinate systems. For all antennas except those with X-Y mounts, the coordinate systems are azimuth-elevation and hour angle-declination. The antennas with X-Y mounts show azimuth-elevation and X-Y coordinates.

Charts showing hour angle-declination coordinates can be used to provide an elevation profile (for estimating antenna gain and noise temperature) for spacecraft at planetary distances where the declination remains constant for an entire tracking pass. The hour angle curves on these charts have been spaced at increments of 15 degrees so that pass length may conveniently be estimated. These figures were plotted by a program written as a collection of Microsoft Excel 97/98 macros. This program is available for download (1.1 Mbytes) from the 810-005 web site (<http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/>). This file also contains the land mask data, which can be used to accurately calculate spacecraft rise and set times.

3 *Proposed Capabilities*

3.1 *DSS 55 Implementation*

A new 34-m BWG station, DSS 55, is under construction at the MDSCC. The coverage capability will be the same as DSS 54 and the horizon mask will be approximately the same as DSS 54.

3.2 *DSS 65 Relocation*

The DSS 65 antenna has experienced differential settling of its foundation since its construction. Attempts to ameliorate the situation have proven unsuccessful and a decision has been made to construct a new foundation approximately 58 m east of the present location and move the antenna. The coverage capability and horizon mask are not expected to be changed significantly by the move.

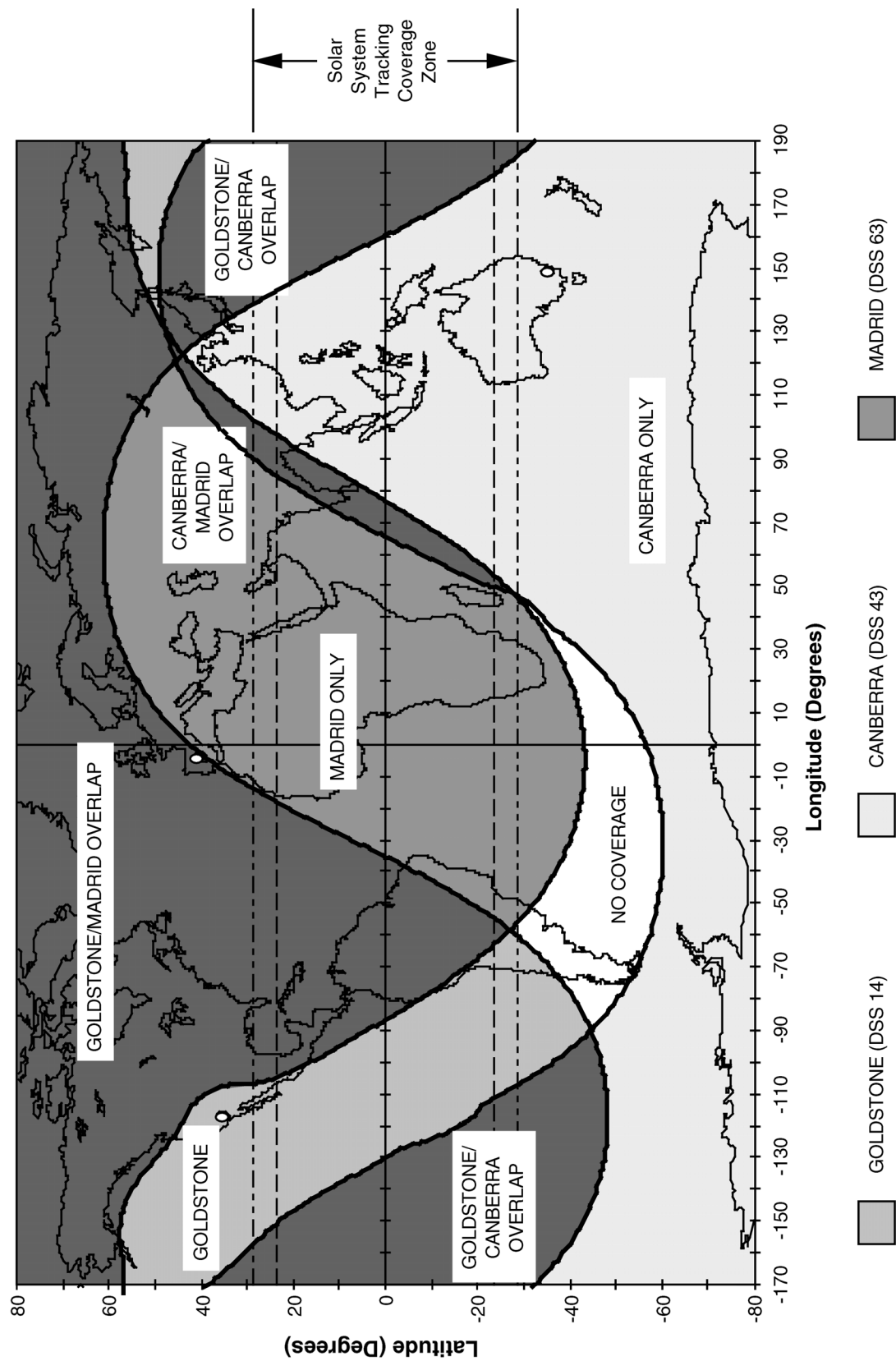


Figure 2. DSN 70-m Subnet Receive Coverage, Planetary Spacecraft

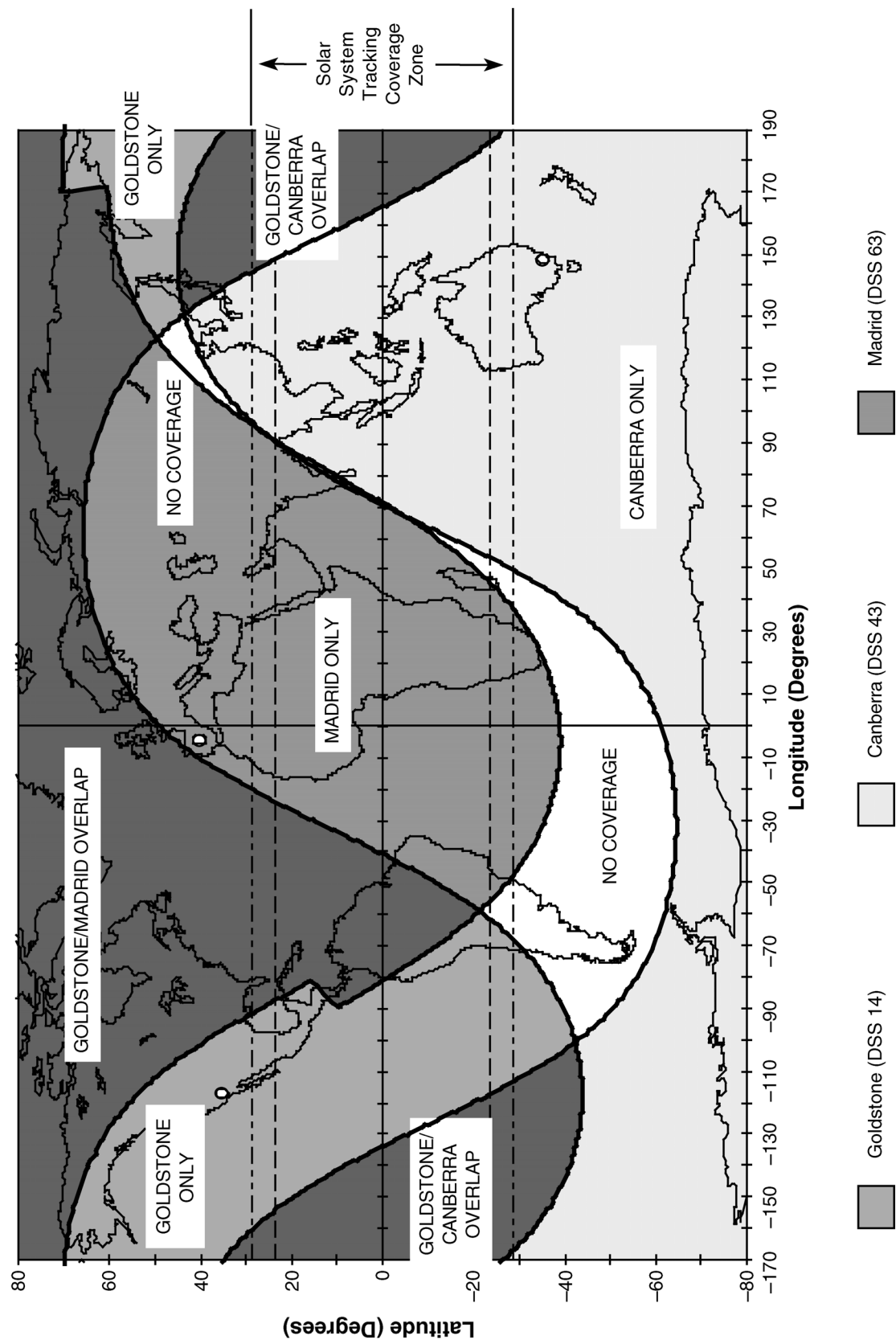


Figure 3. DSN 70-m Subnet Transmit Coverage, Planetary Spacecraft.

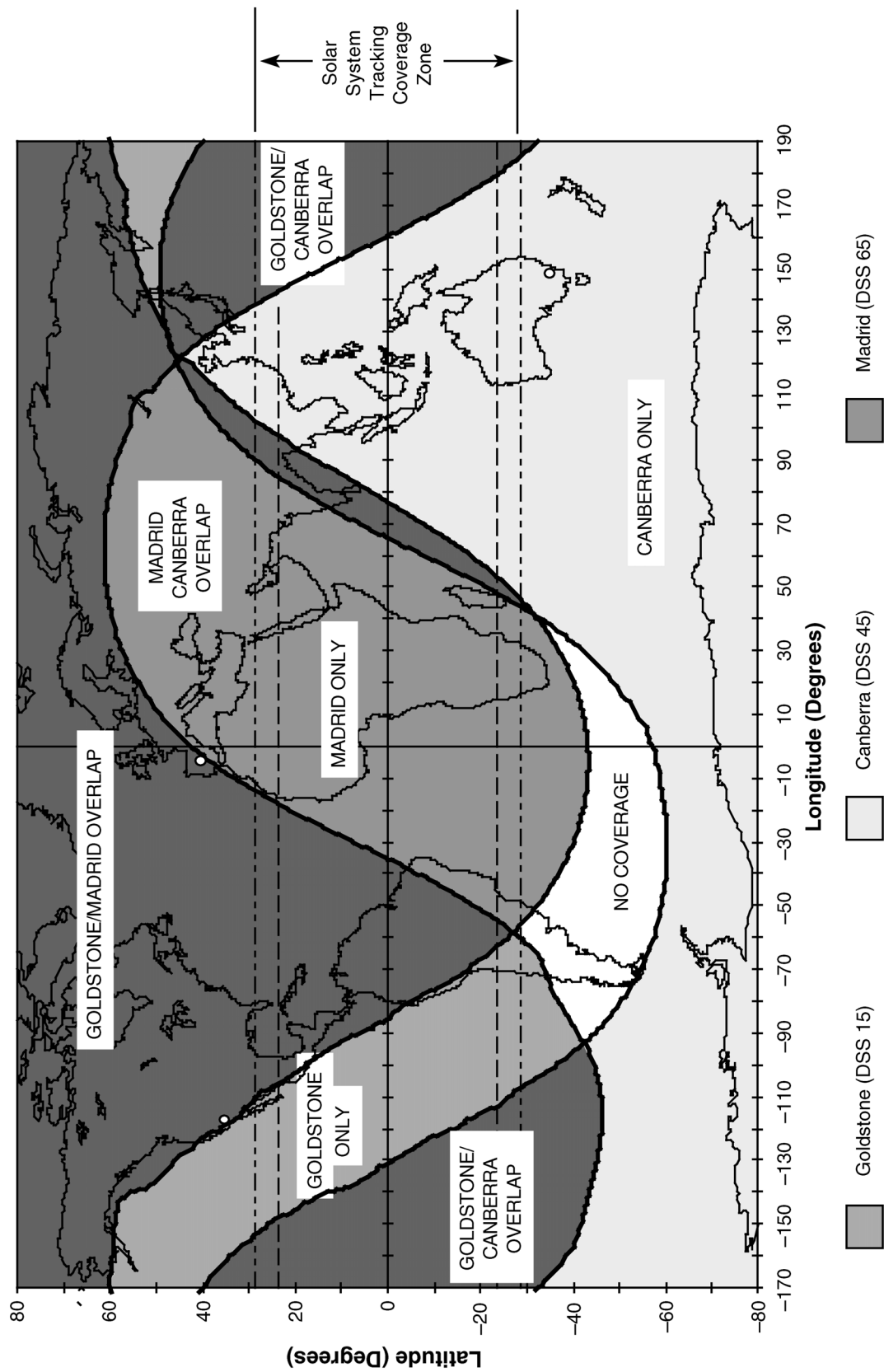


Figure 4. DSN 34-m HEF Subnet Receive Coverage, Planetary Spacecraft.

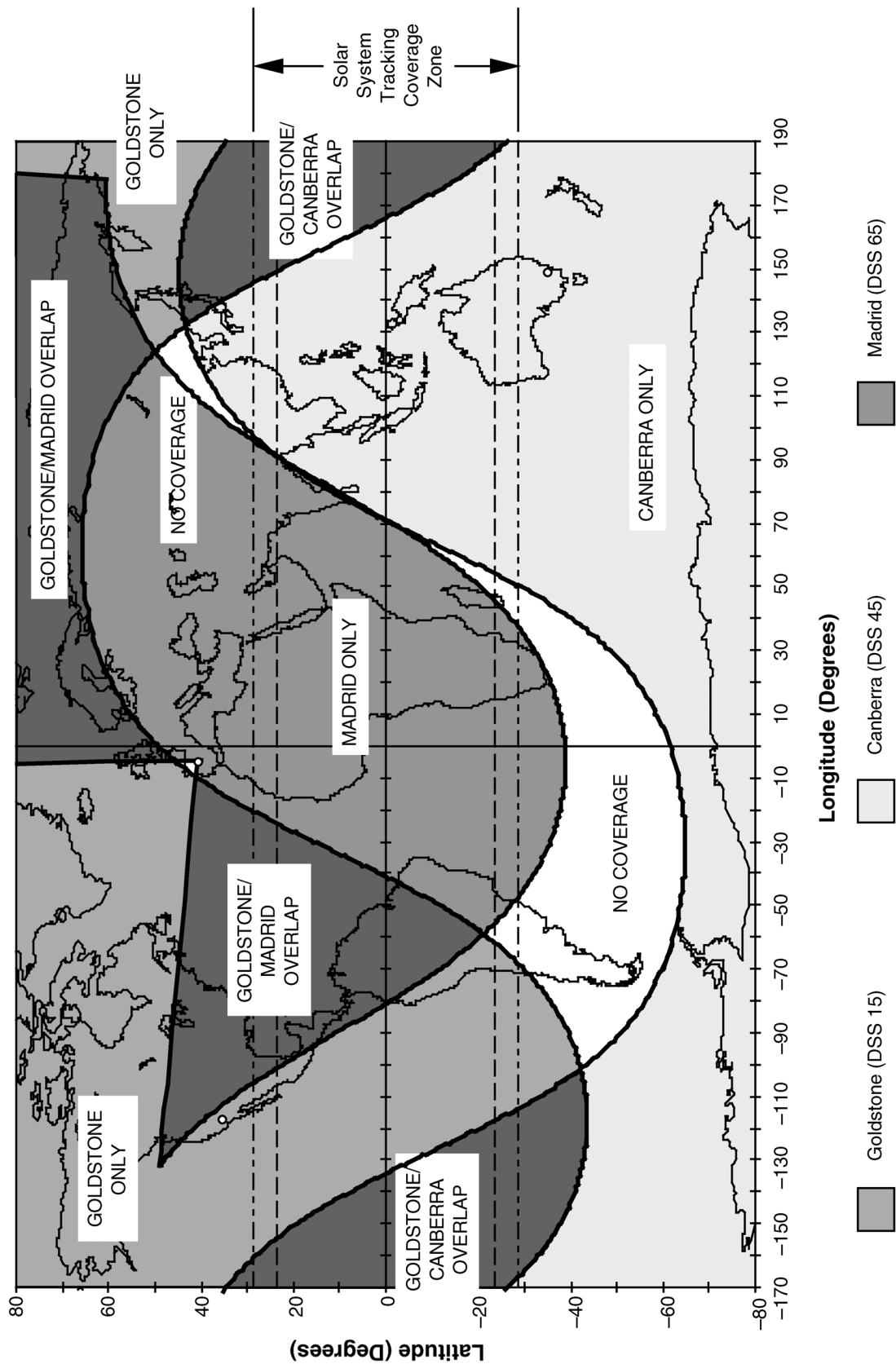


Figure 5. DSN 34-m HEF Subnet Transmit Coverage, Planetary Spacecraft

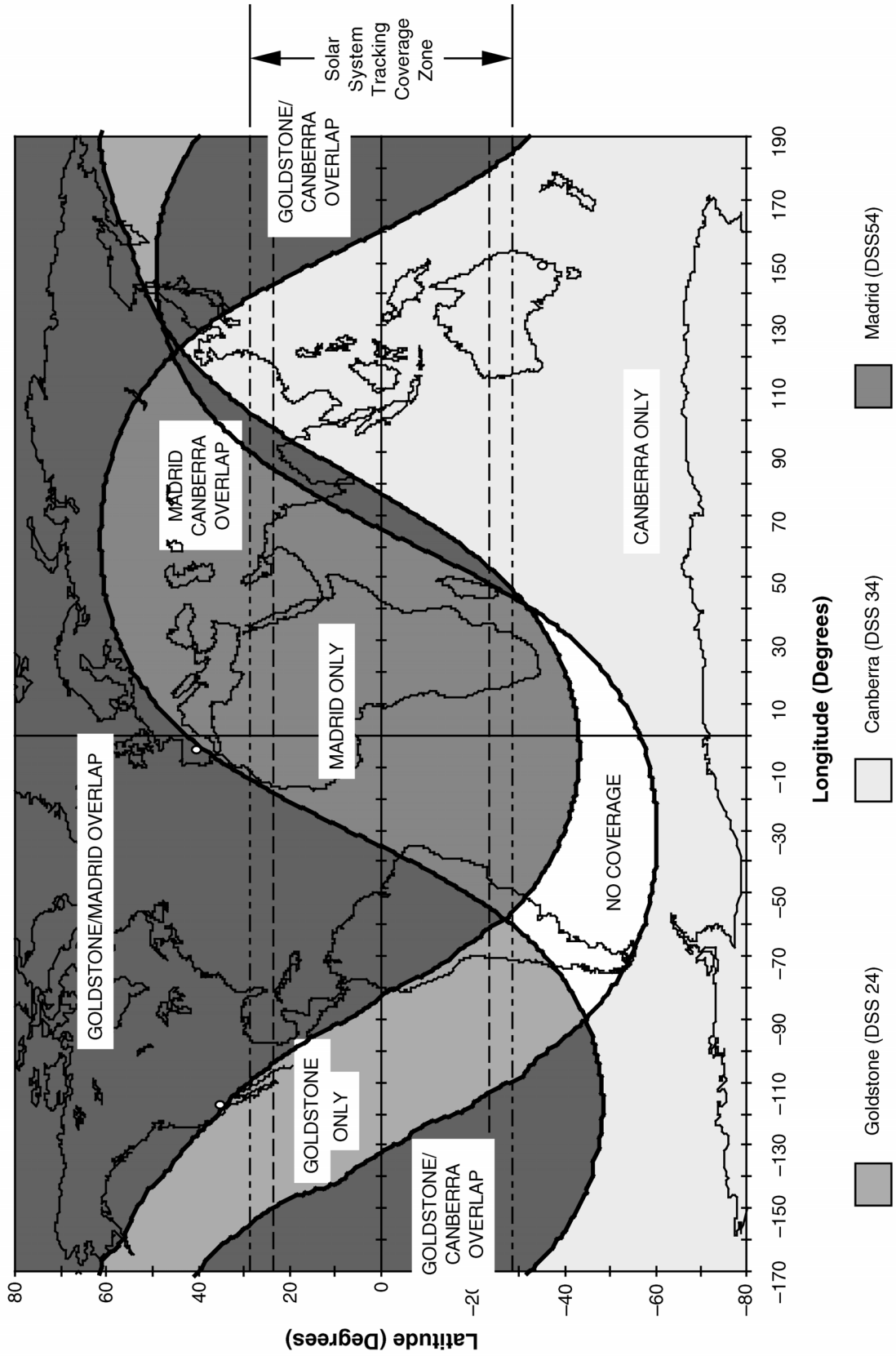


Figure 6. DSN 34-m BWG Antennas Receive Coverage, Planetary Spacecraft

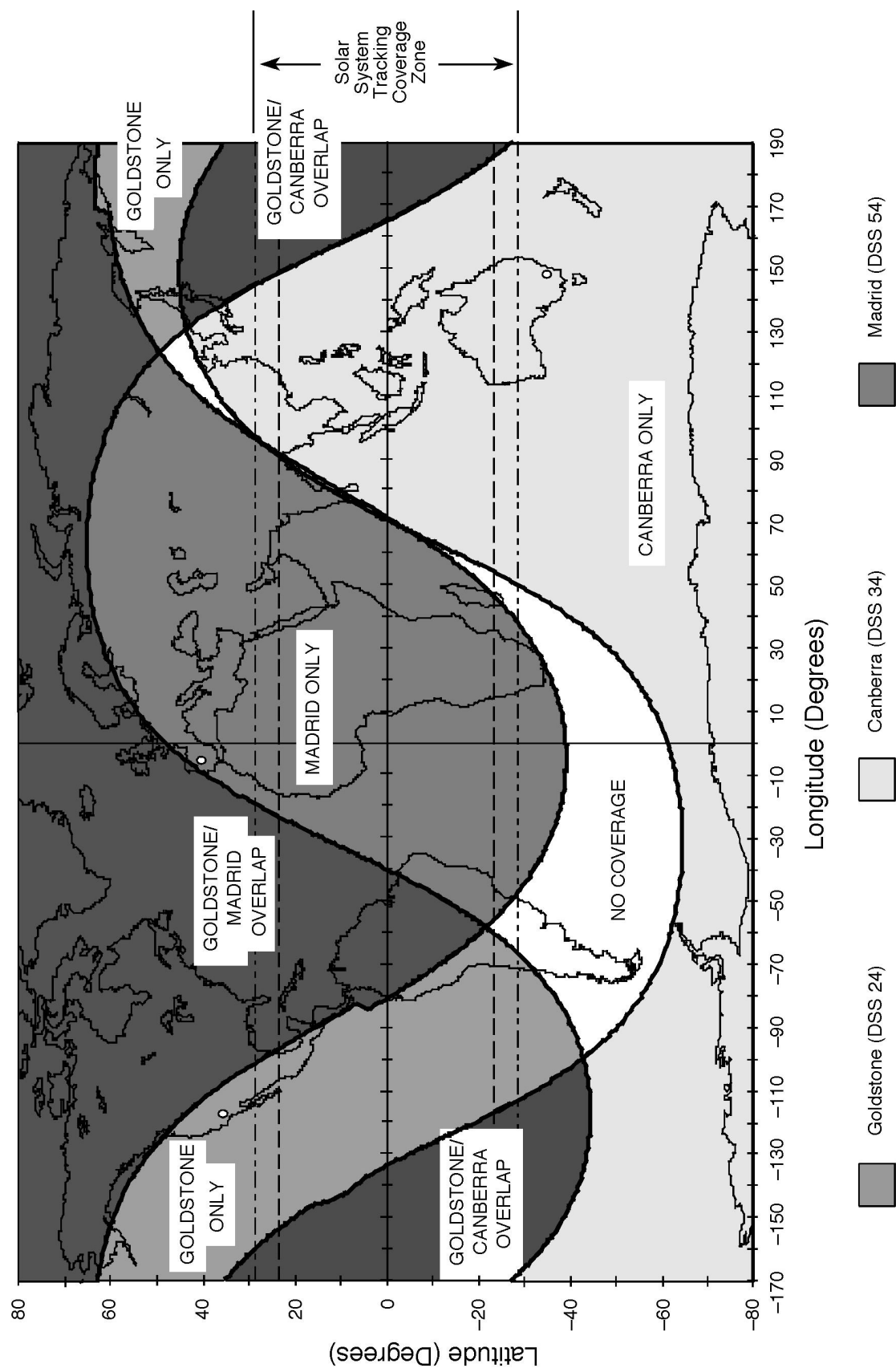


Figure 7. DSN 34-m BWG Antennas Transmit Coverage, Planetary Spacecraft

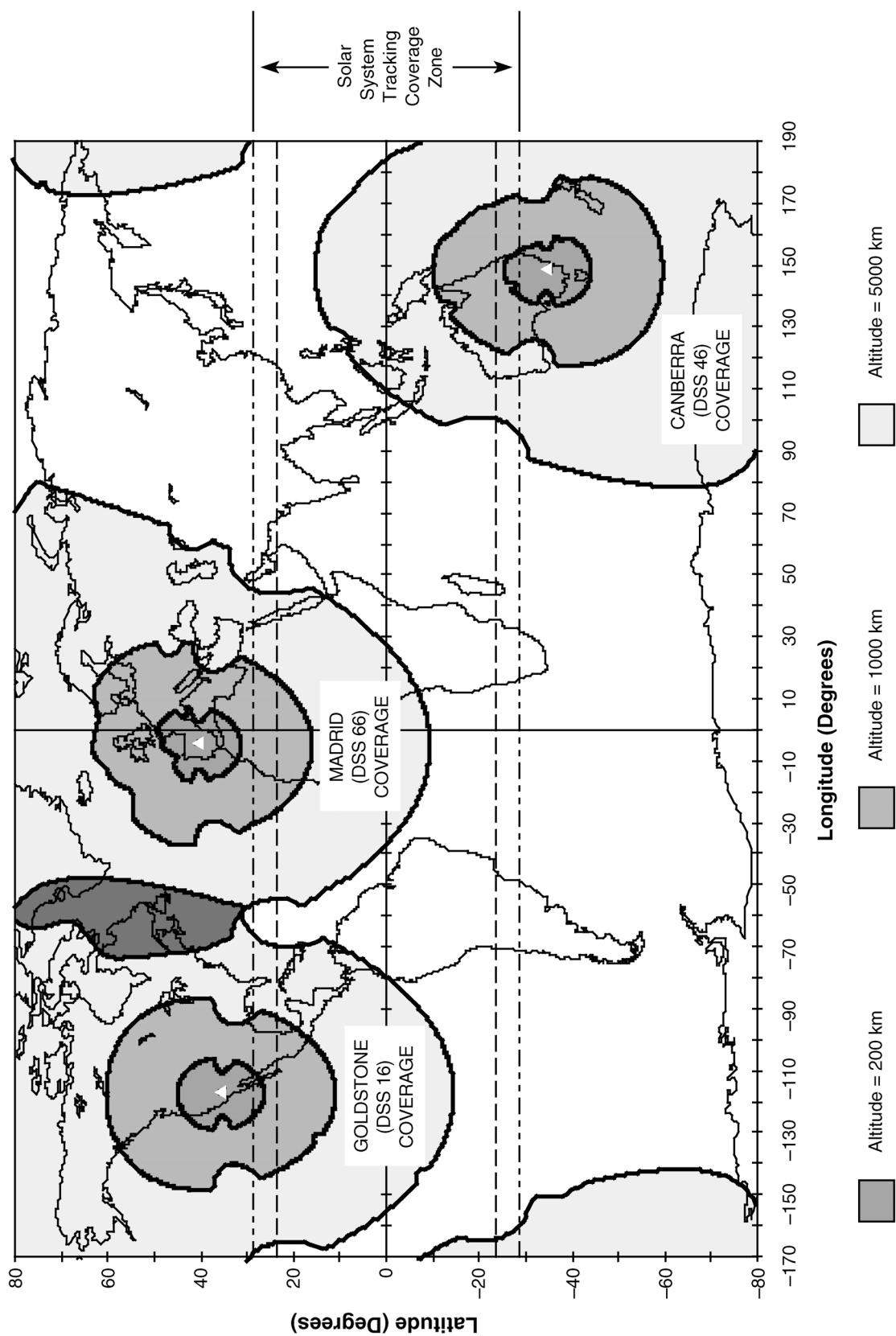


Figure 8. DSN 26-m Subnet Receive Coverage, Earth Orbiter Spacecraft

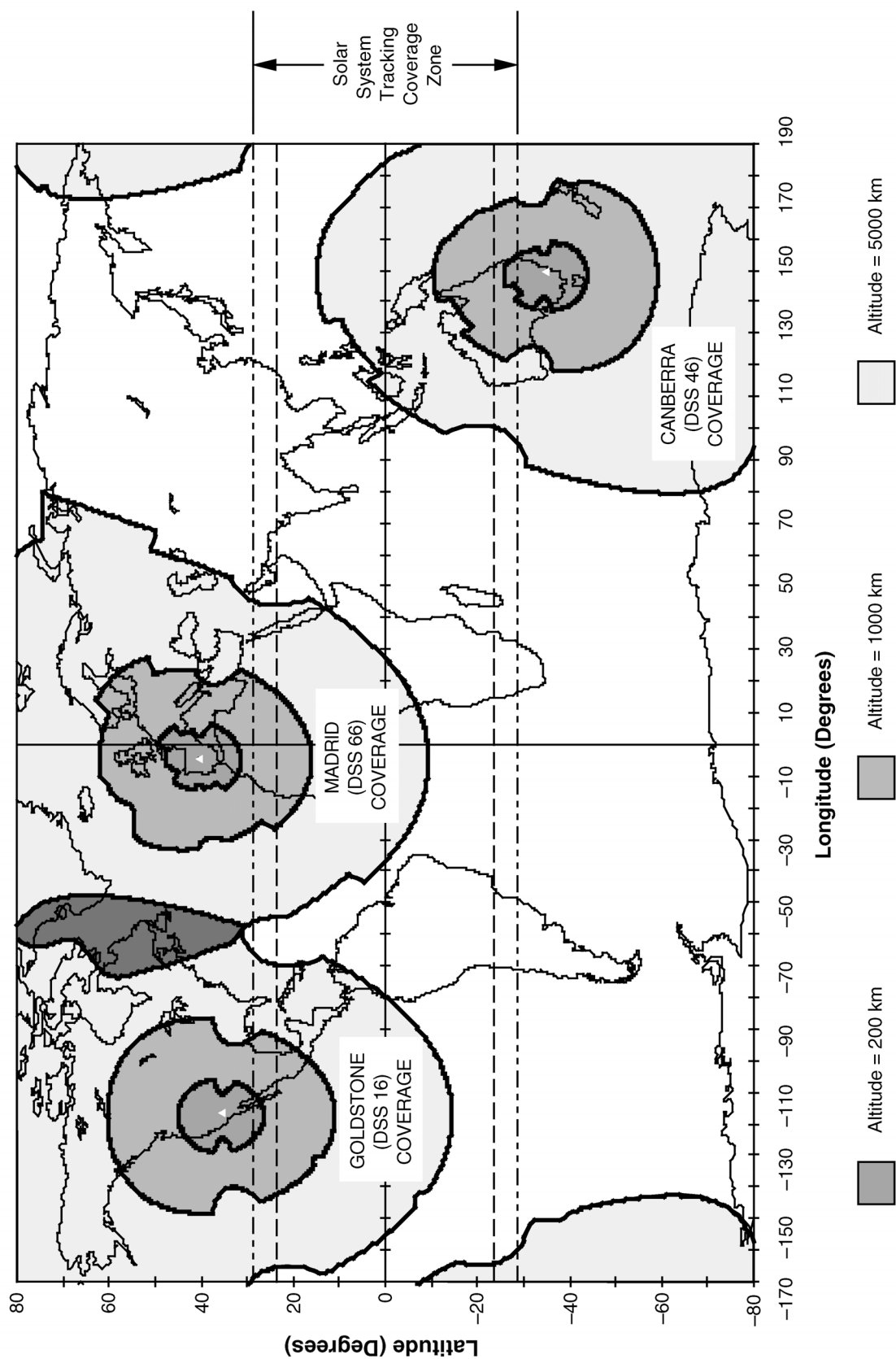


Figure 9. DSN 26-m Subnet Transmit Coverage, Earth Orbiter Spacecraft

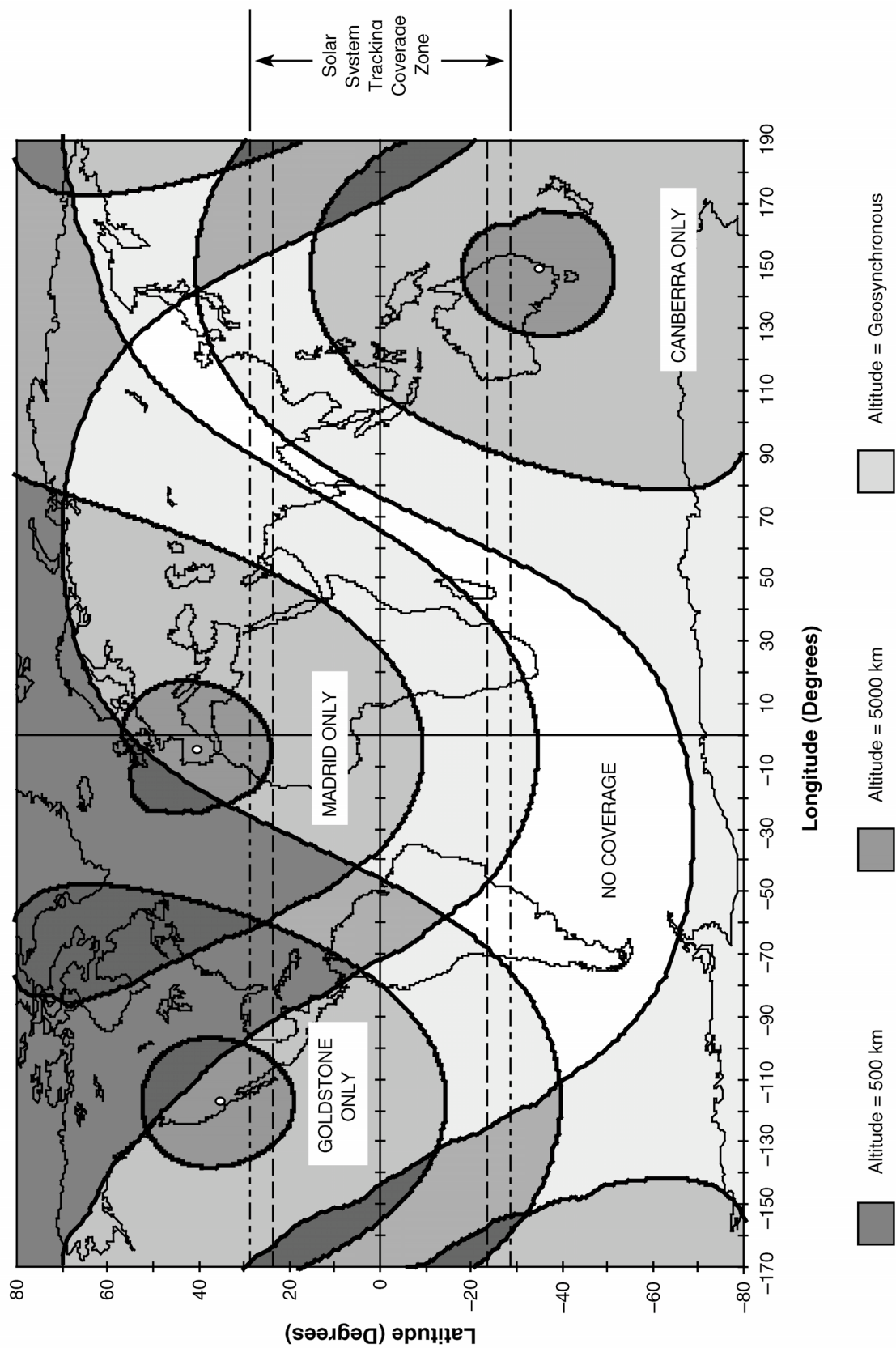


Figure 10. DSN 34-m BWG Antennas Receive Coverage, Earth Orbiter Spacecraft

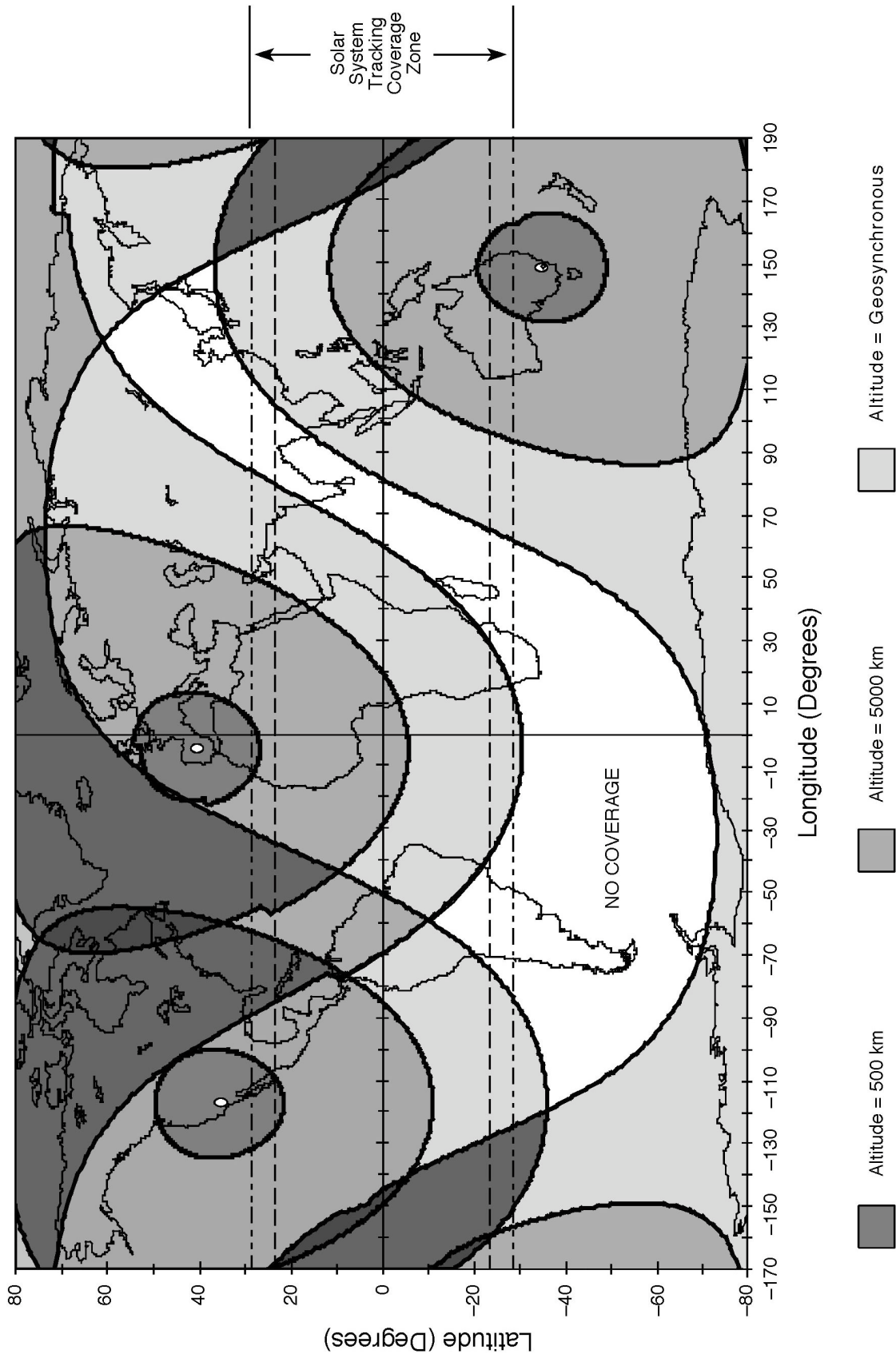


Figure 11. DSN 34-m BWG Antennas Transmit Coverage, Earth-Orbiter Spacecraft

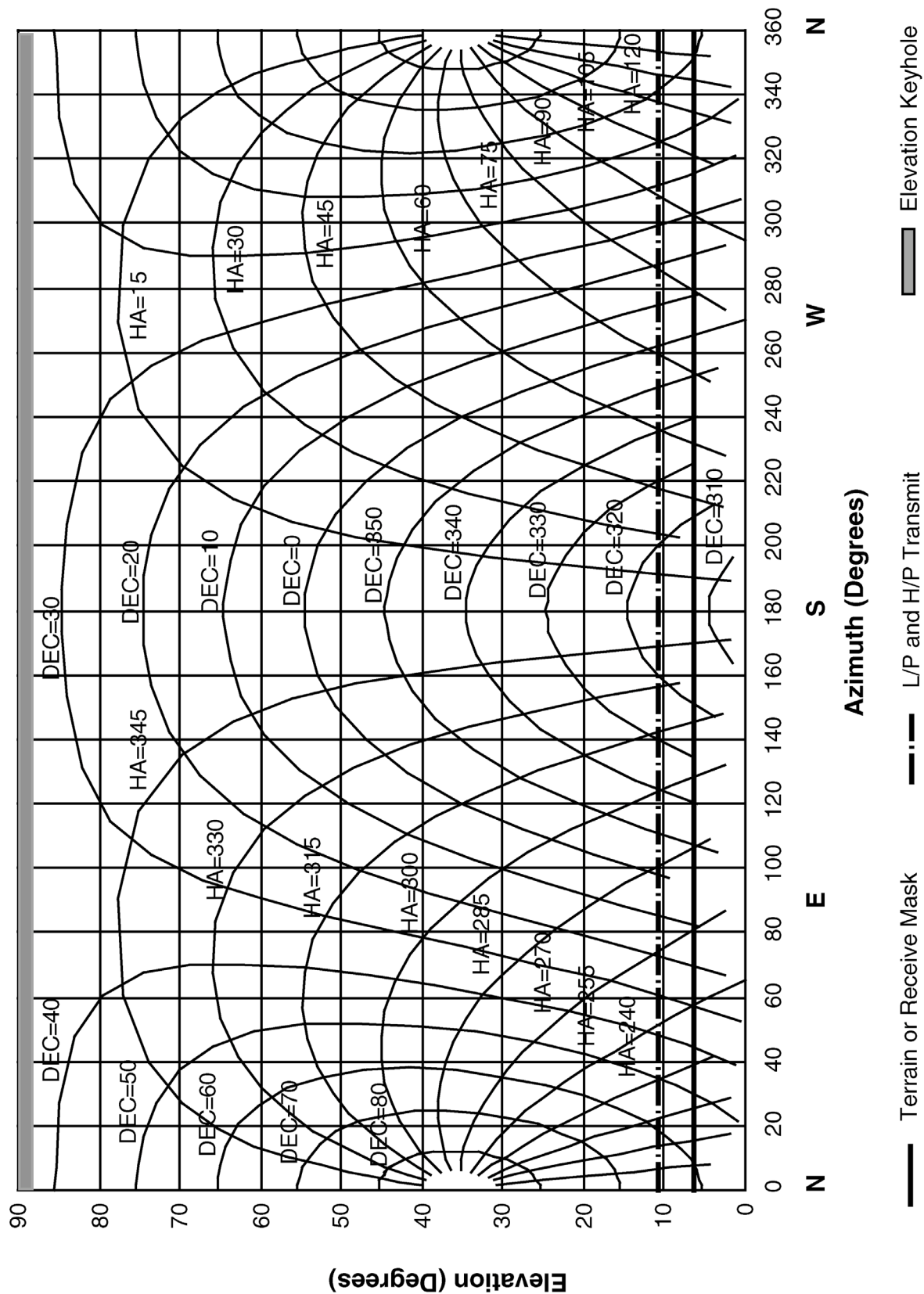


Figure 12. DSS 14 Hour-Angle and Declination Profiles and Horizon Mask

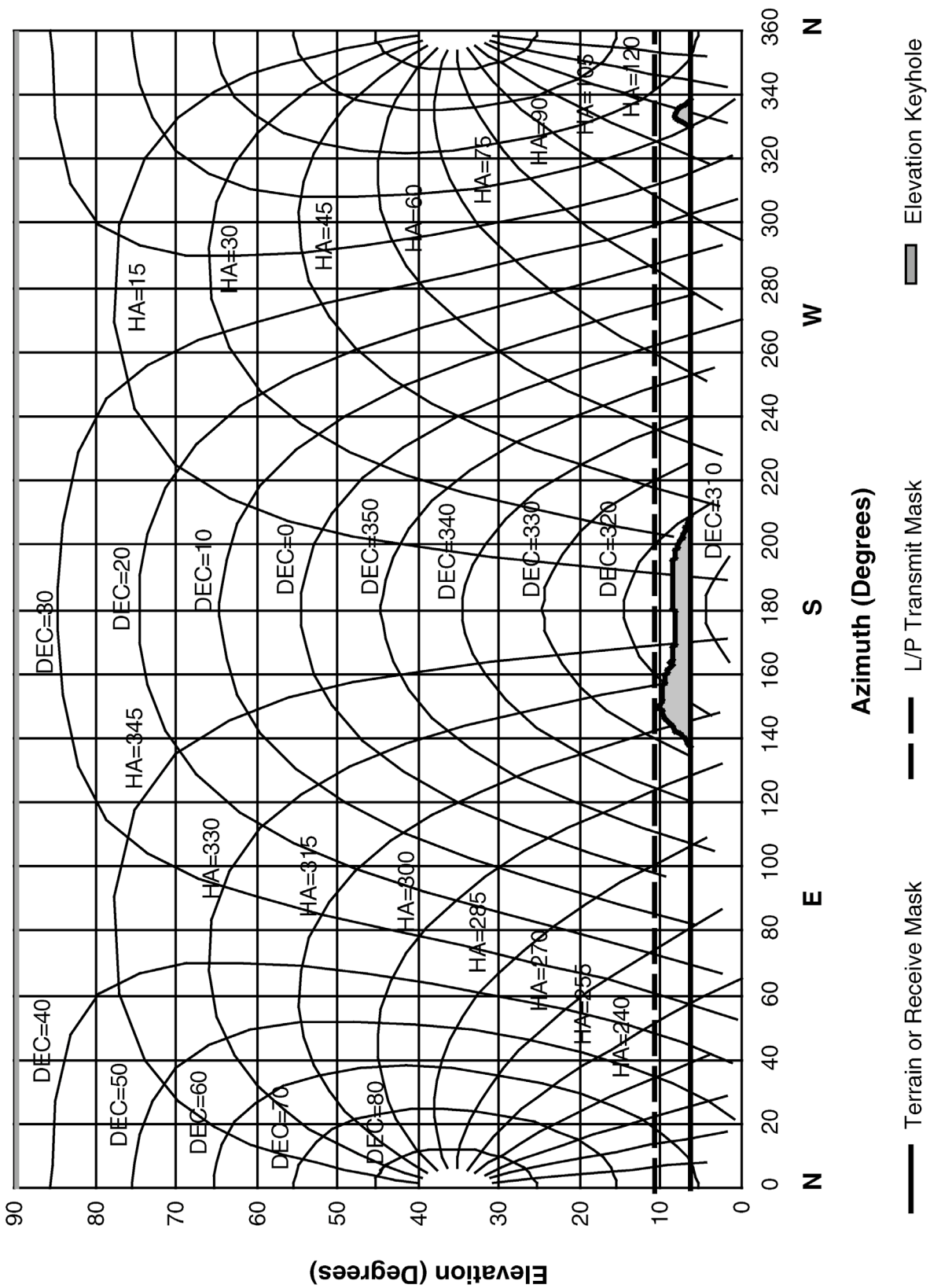


Figure 13. DSS 15 Hour-Angle and Declination Profiles and Horizon Mask

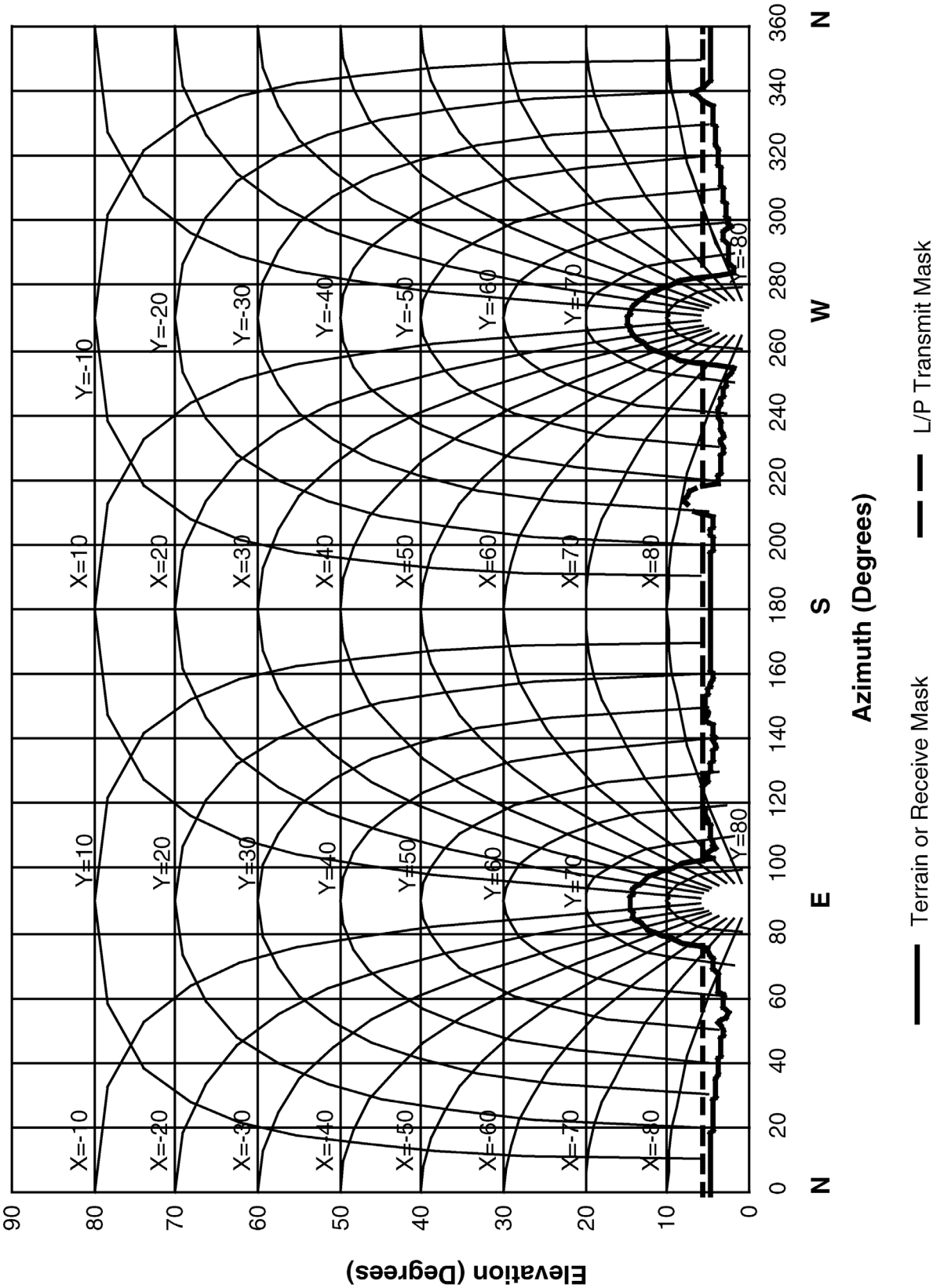


Figure 14. DSS 16 X-Y Profiles and Horizon Mask



Figure 15. DSS 24 Hour-Angle and Declination Profiles and Horizon Mask

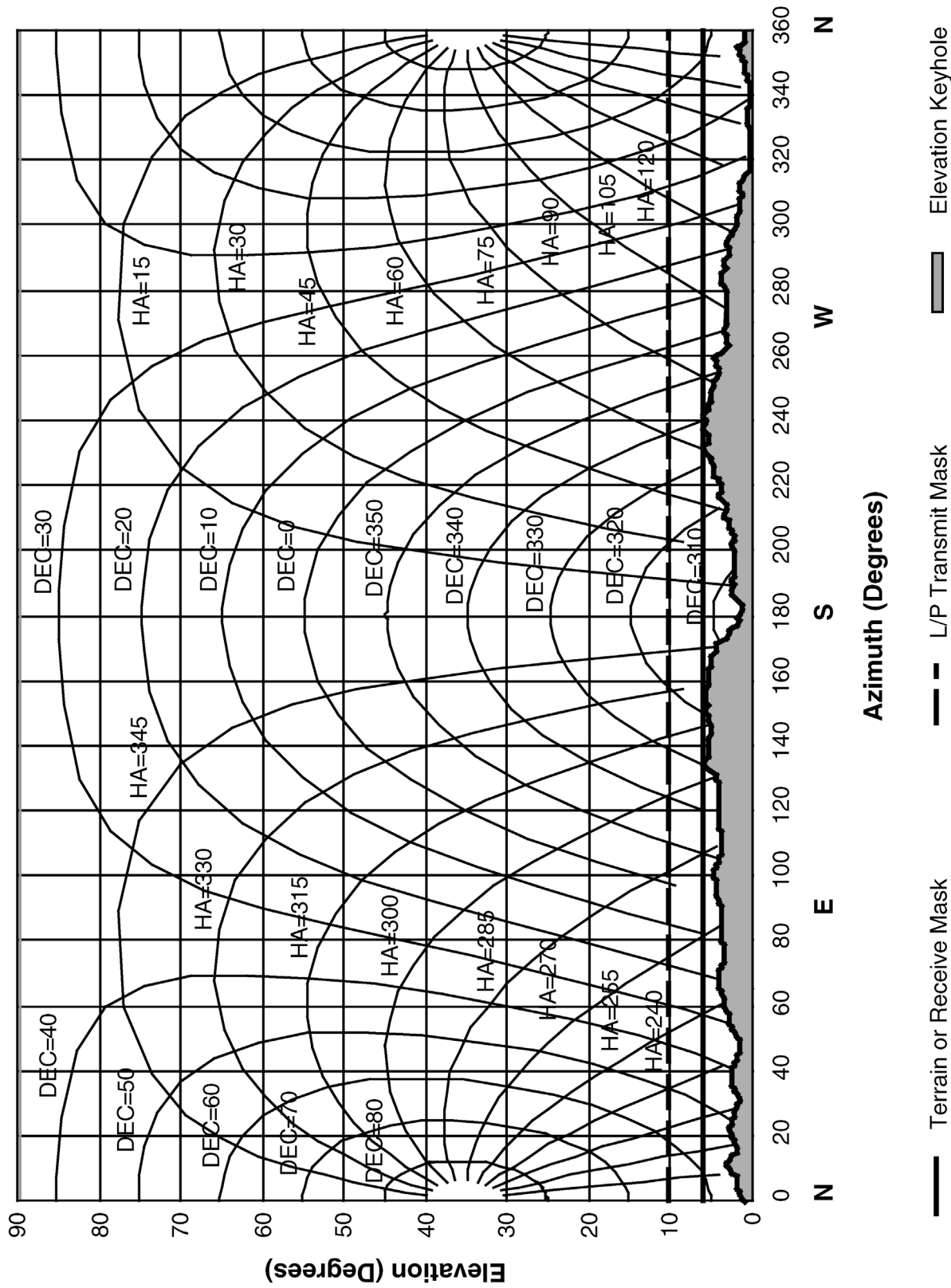


Figure 16. DSS 25 Hour-Angle and Declination Profiles and Horizon Mask

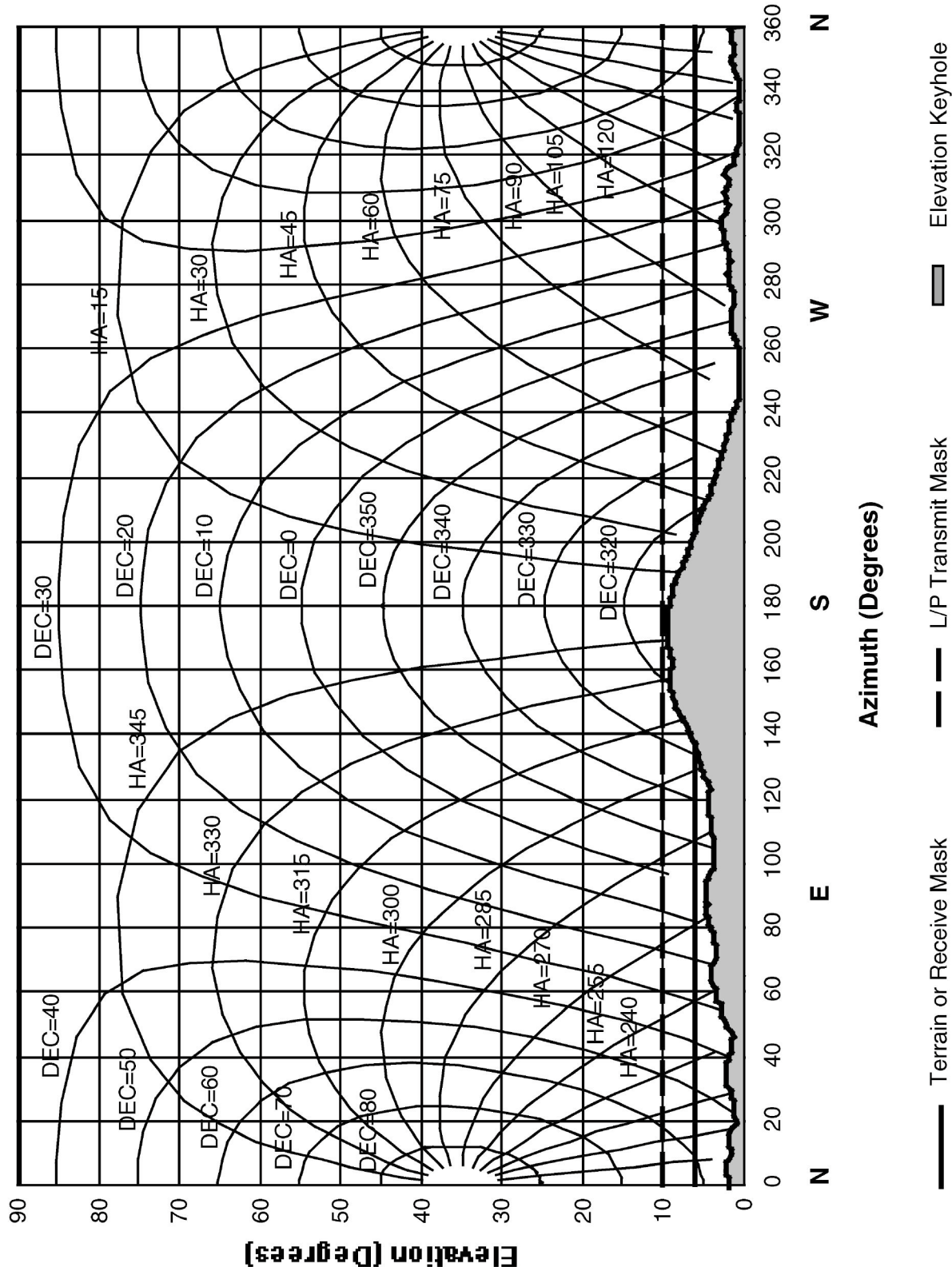


Figure 17. DSS 26 Hour-Angle and Declination Profiles and Horizon Mask

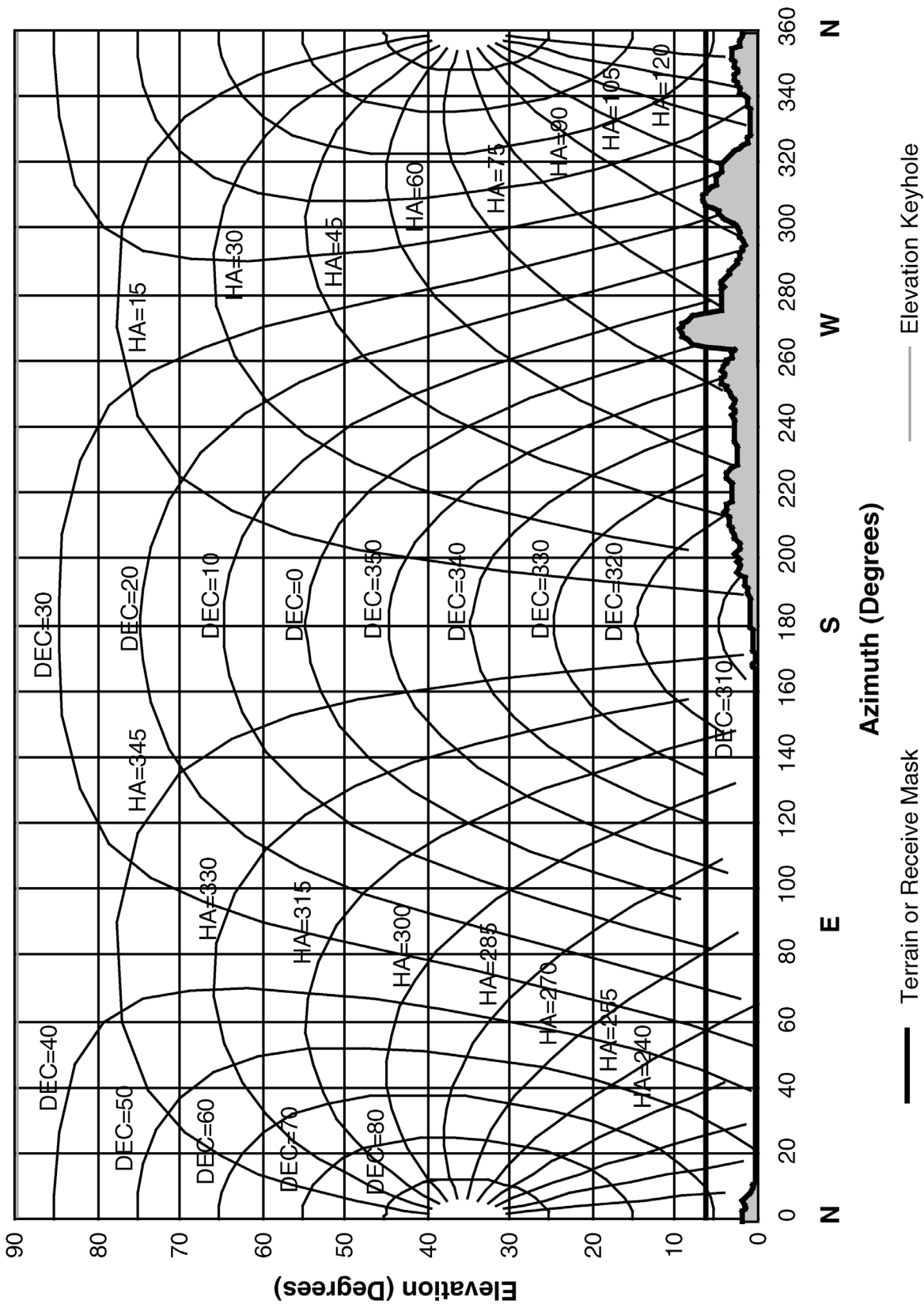


Figure 18. DSS 27 Hour-Angle and Declination Profiles and Horizon Mask.

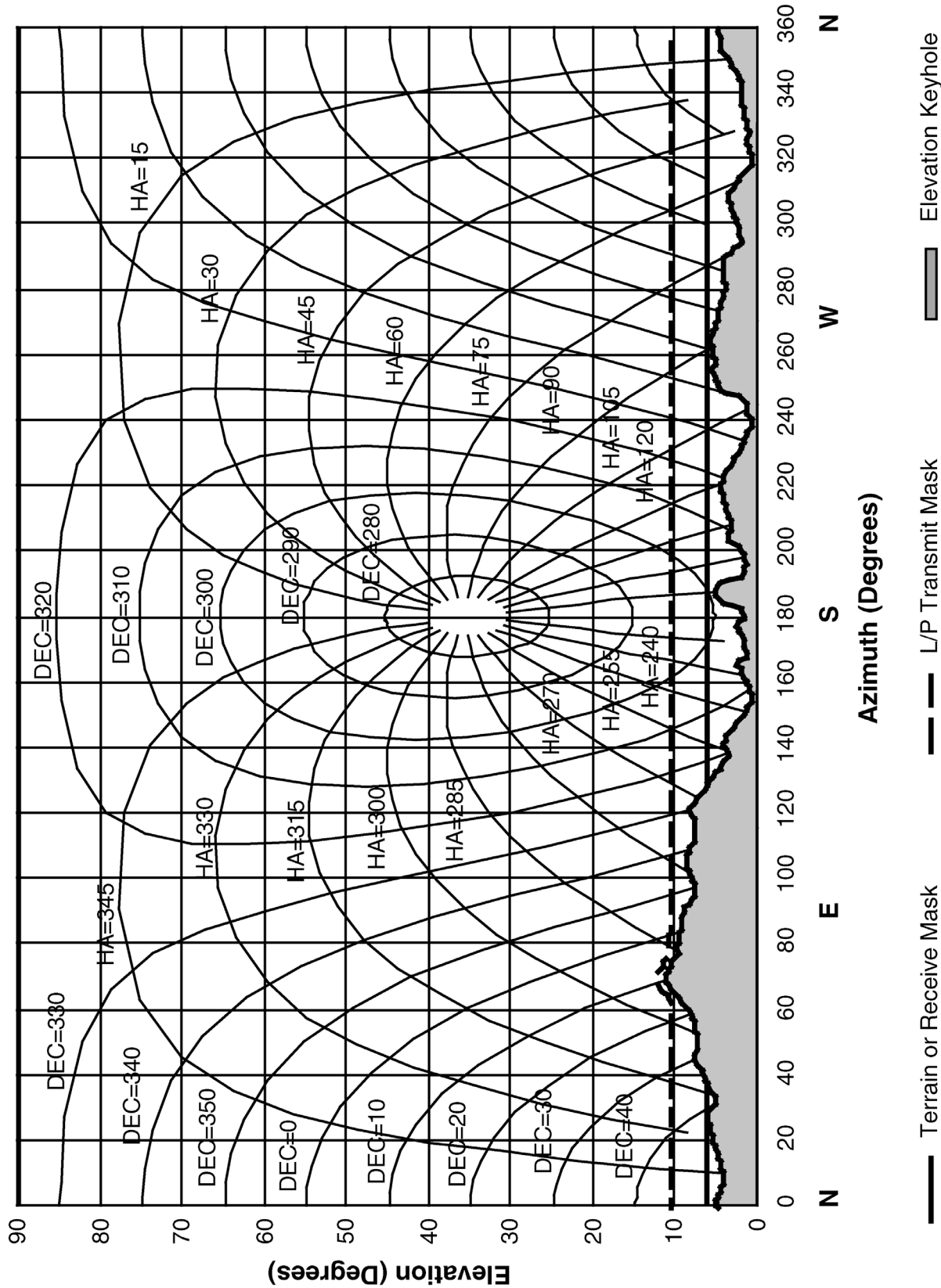


Figure 19. DSS 34 Hour-Angle and Declination Profiles and Horizon Mask

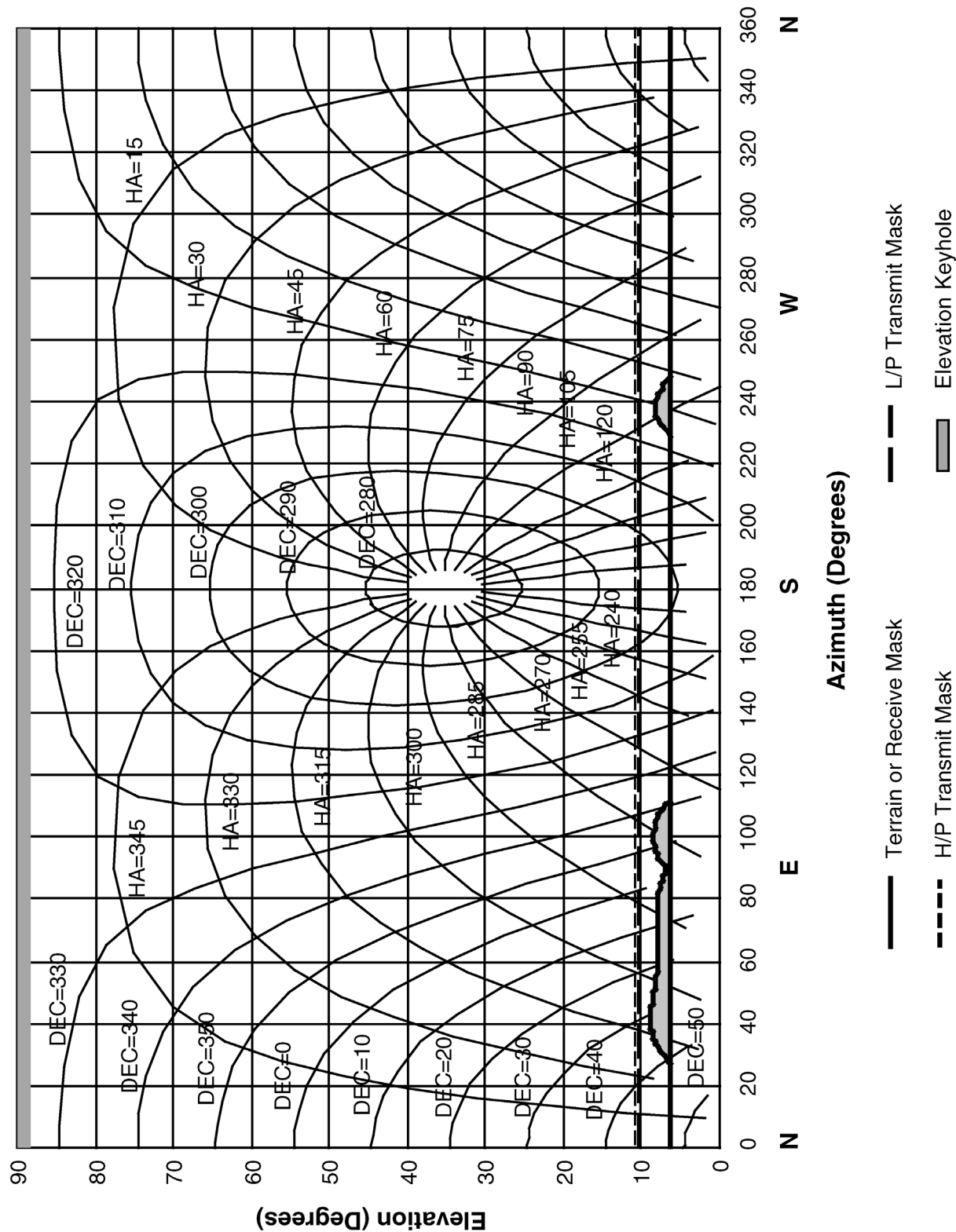


Figure 20. DSS 43 Hour-Angle and Declination Profiles and Horizon Mask

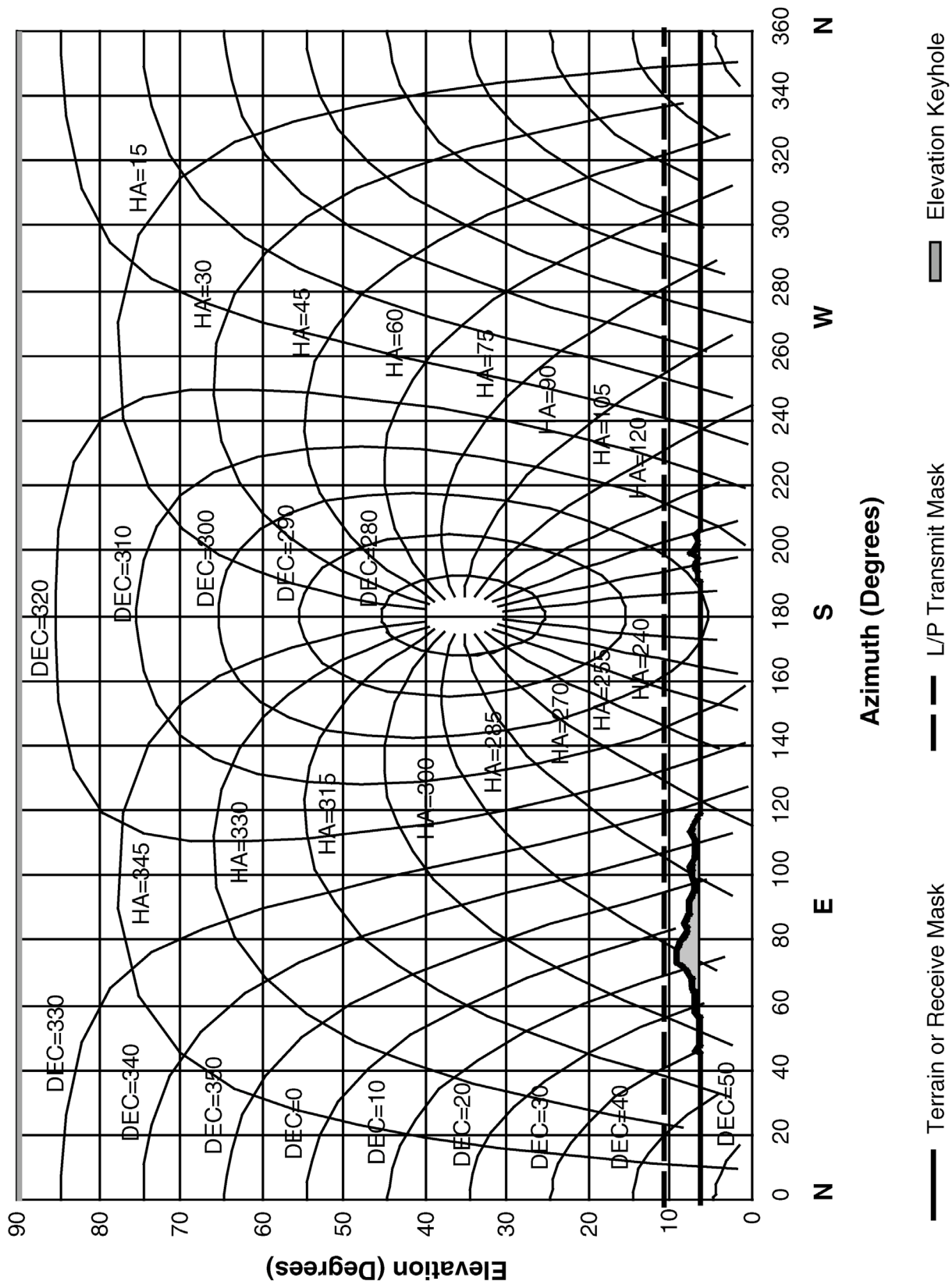


Figure 21. DSS 45 Hour-Angle and Declination Profiles and Horizon Mask

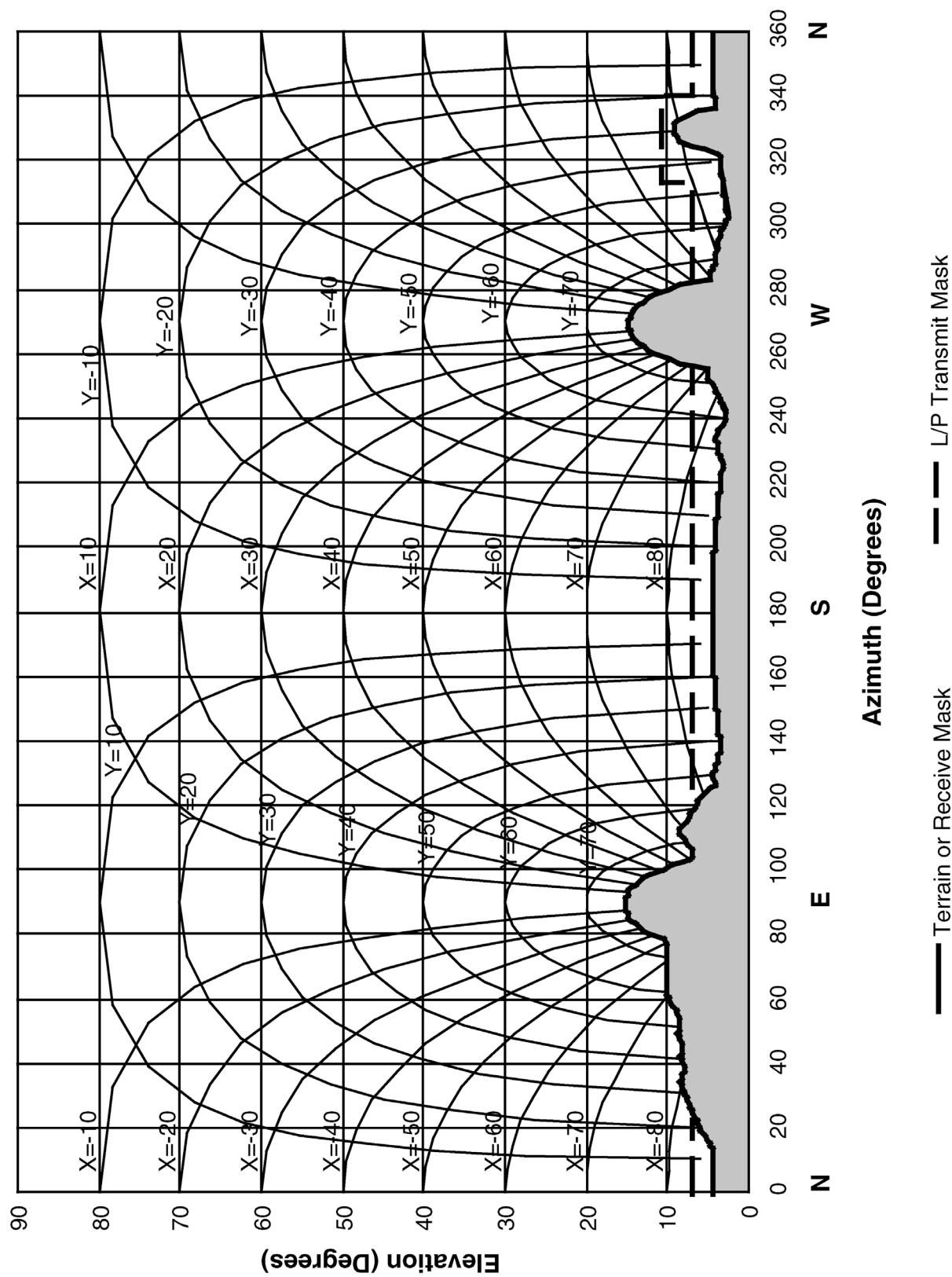


Figure 22. DSS 46 X-Y Profiles and Horizon Mask

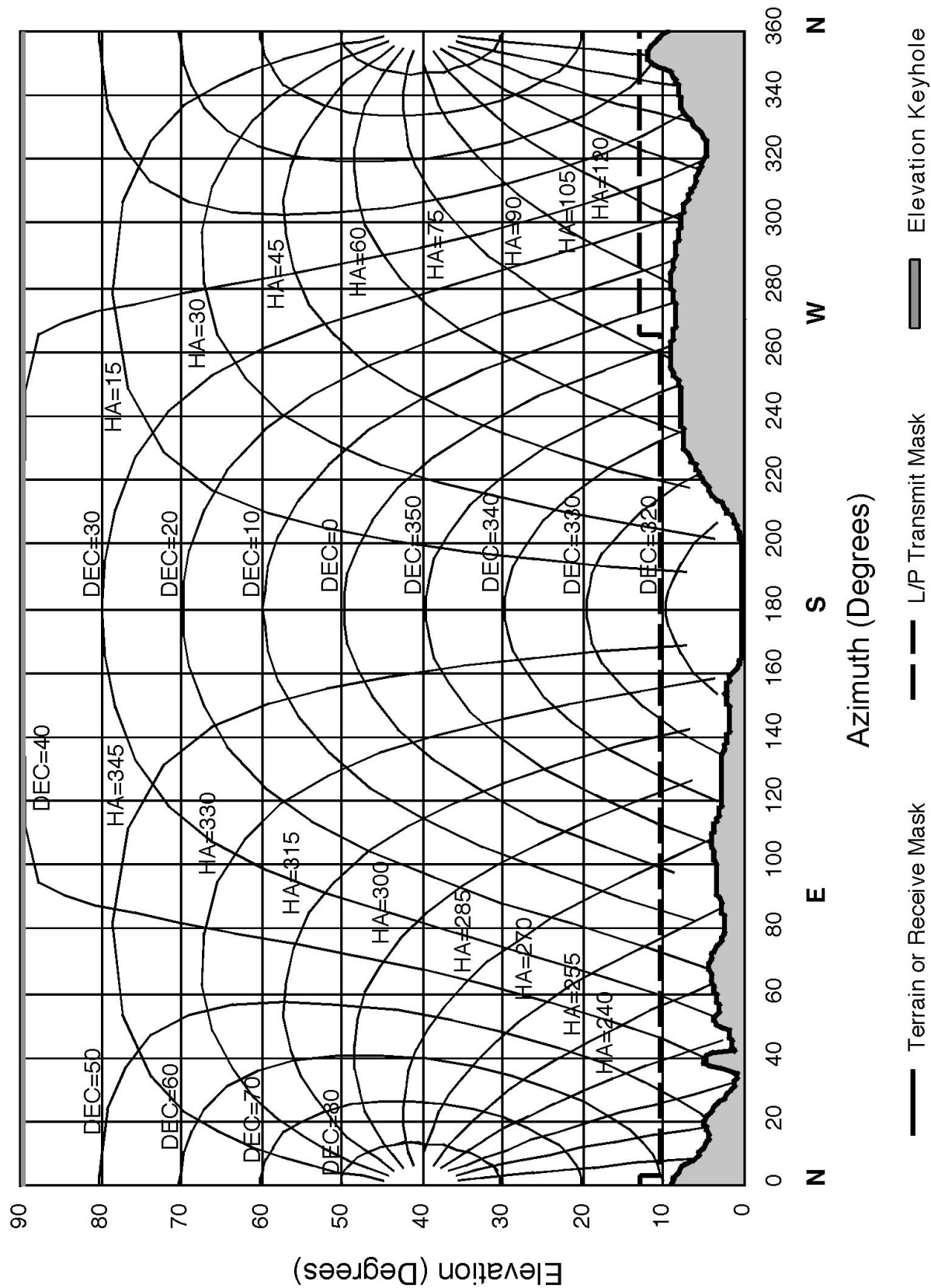


Figure 23. DSS 54 Hour-Angle and Declination Profiles and Horizon Mask

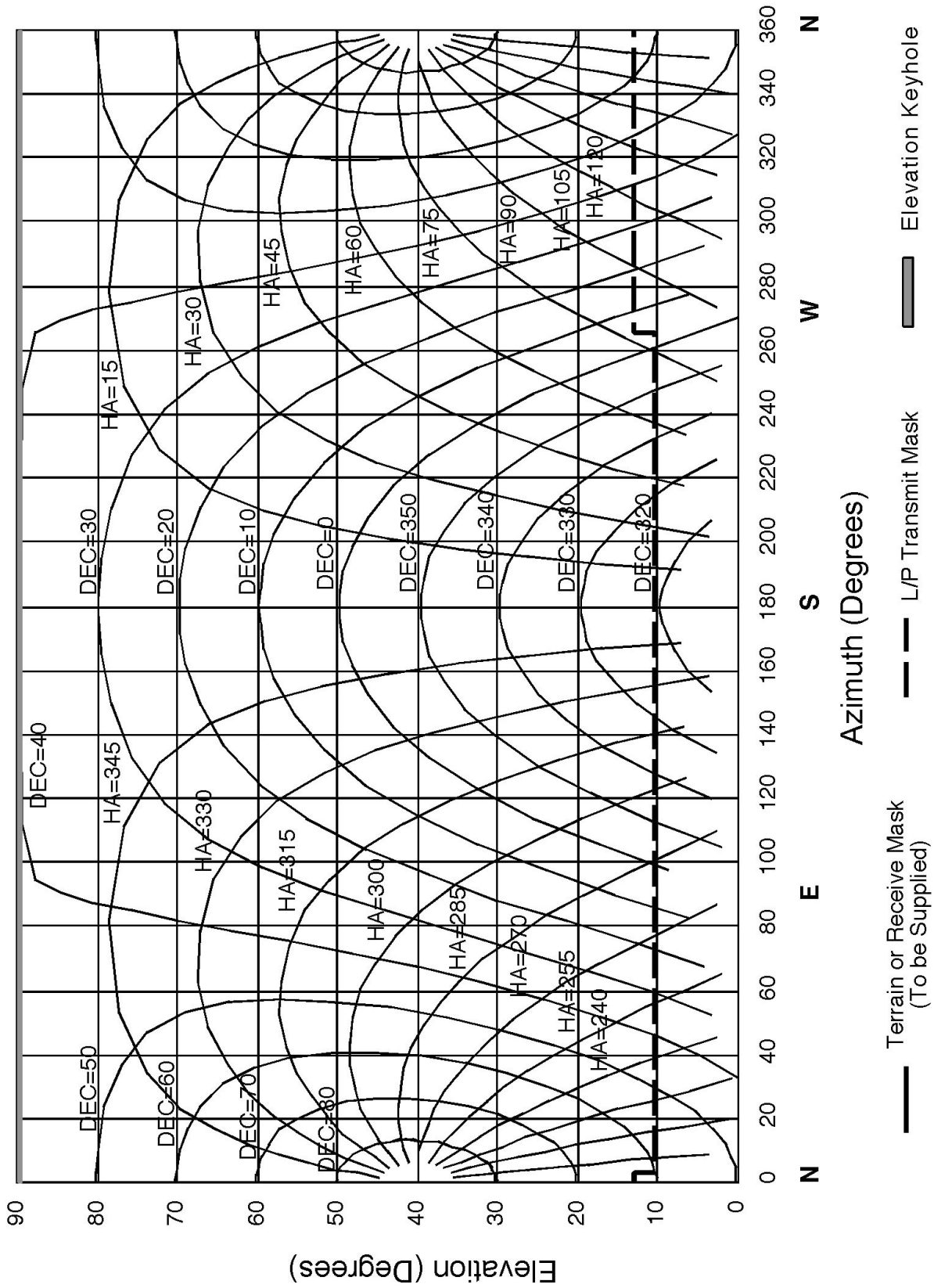


Figure 24. DSS 55 Hour-Angle and Declination Profiles and Horizon Mask

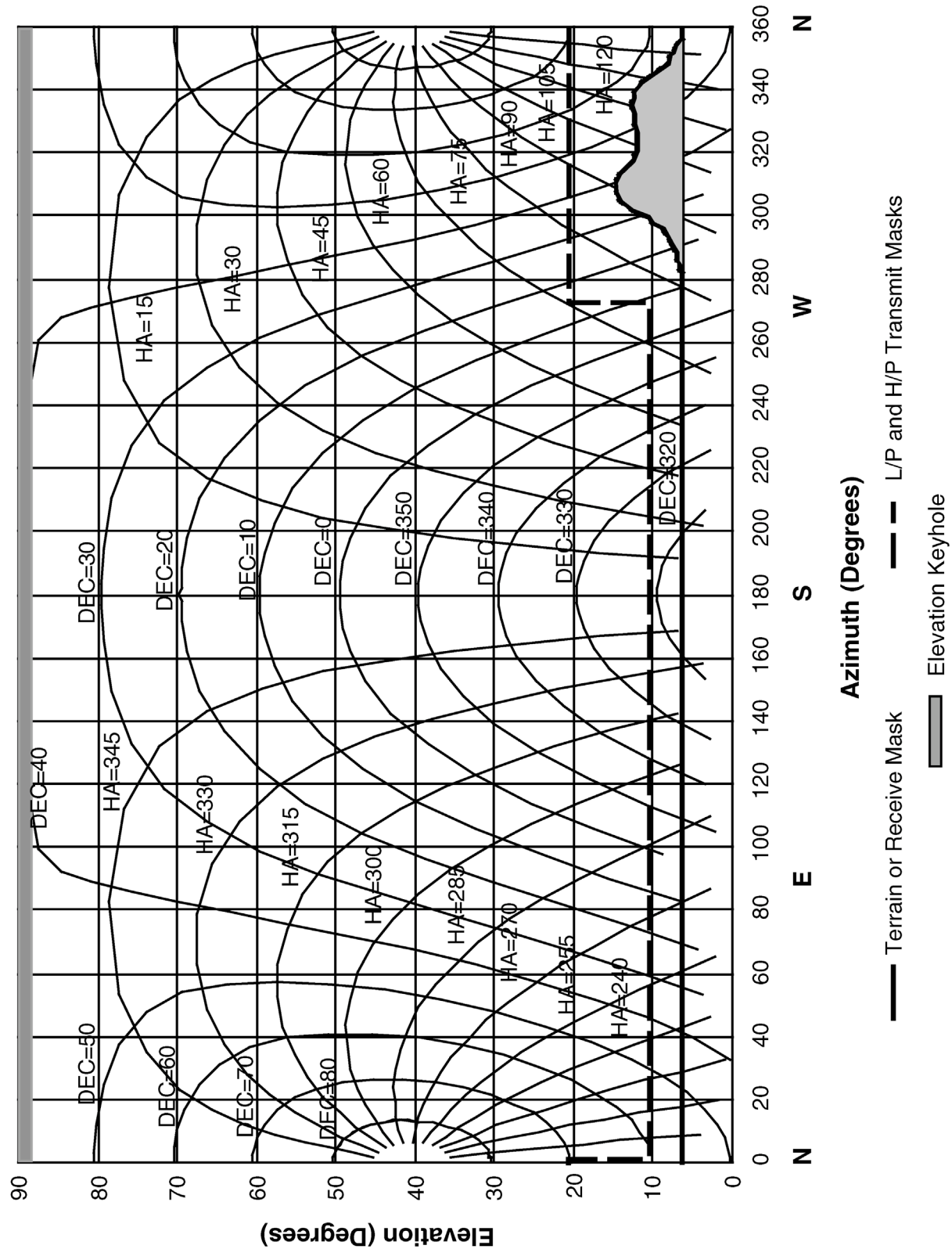


Figure 25. DSS 63 Hour-Angle and Declination Profiles and Horizon Mask

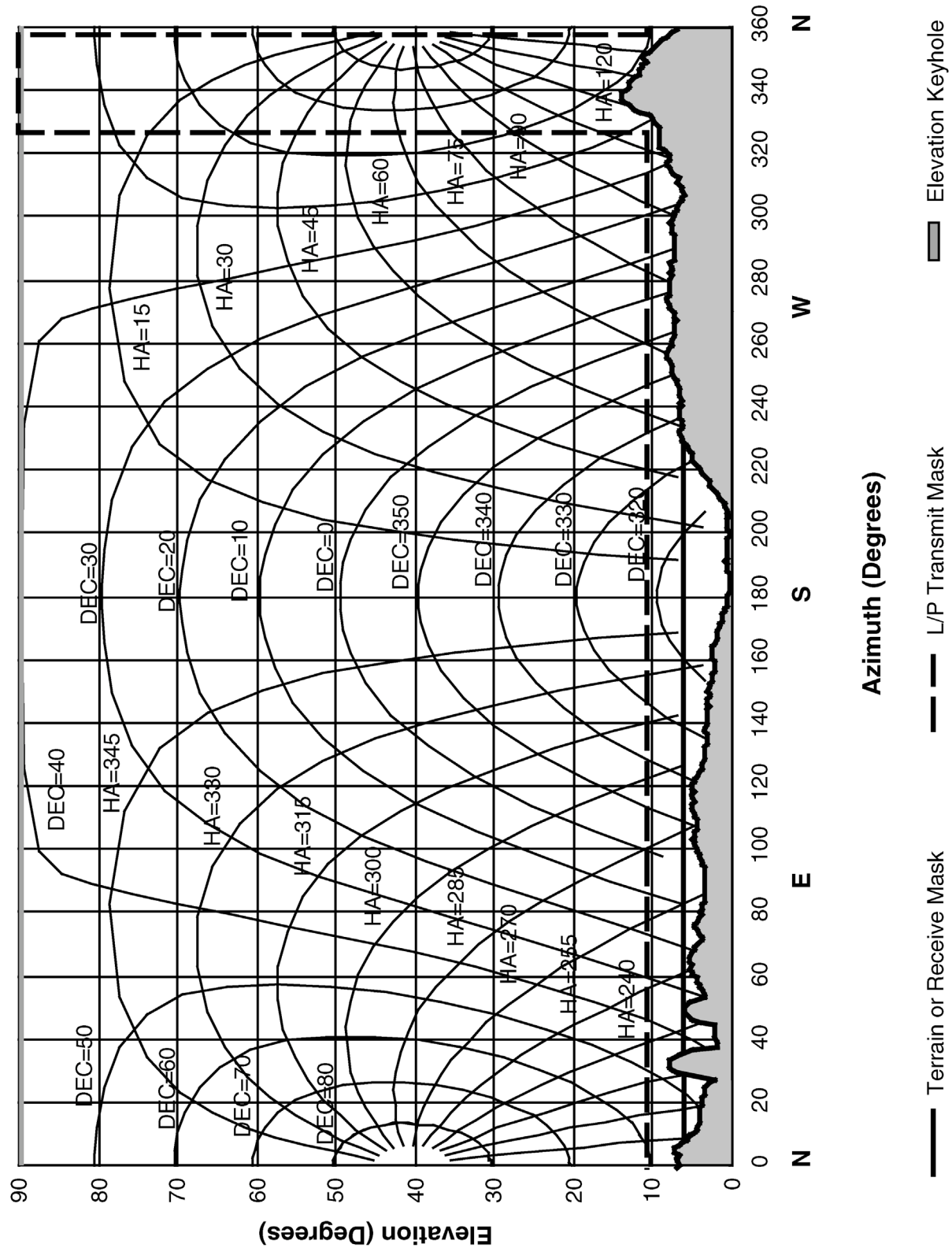


Figure 26. DSS 65 Hour-Angle and Declination Profiles and Horizon Mask

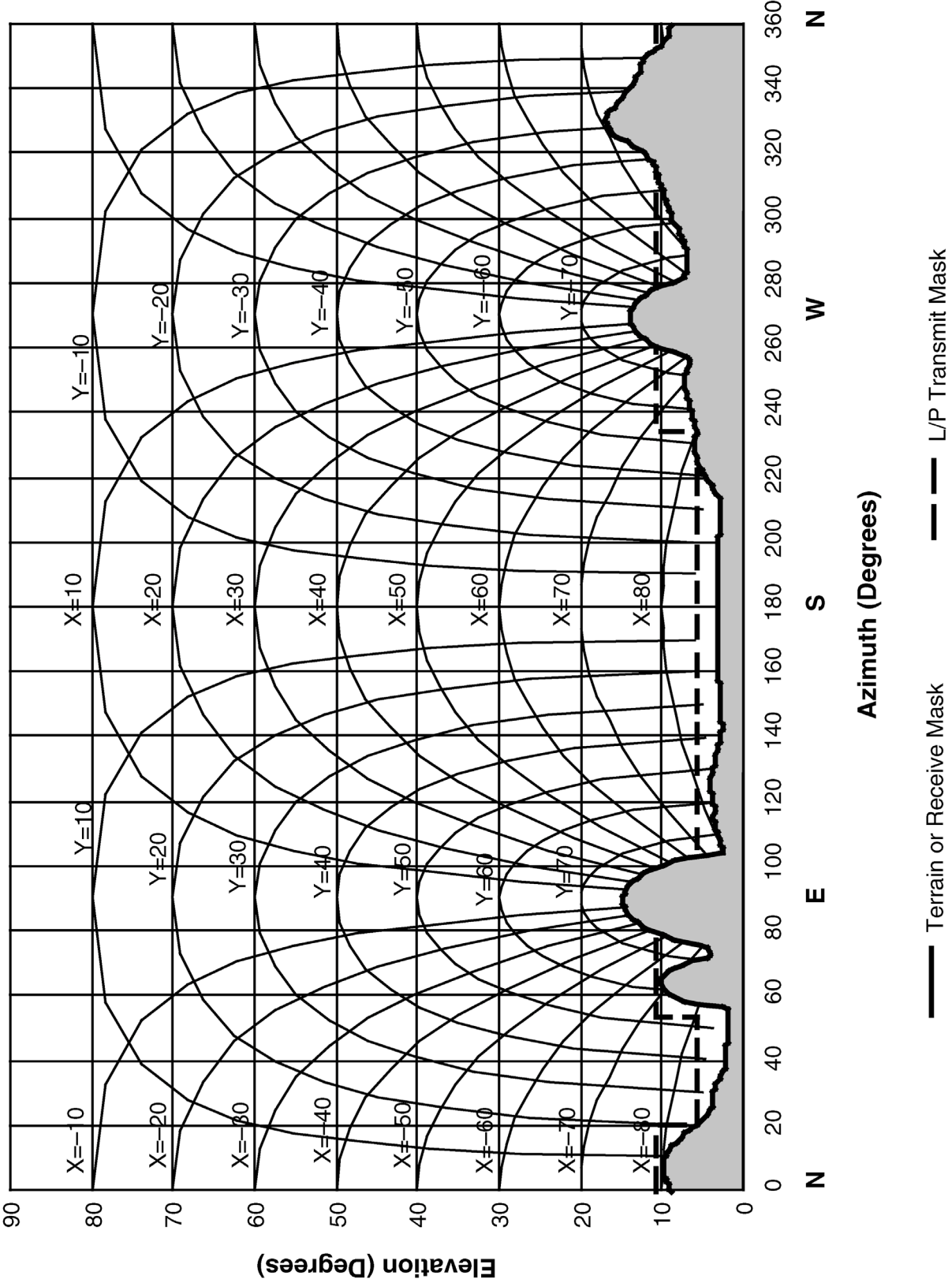


Figure 30. DSS 66 X-Y Profiles and Horizon Mask

Appendix A ***References***

- 1 C. Boucher, Z. Altamimi, and L. Duhem, *Results and analysis of the ITRF93*, IERS Technical Note 18, Observatoire de Paris, October 1994
- 2 B. R. Bowring, "The accuracy of geodetic latitude and height equations," *Survey Review*, 28, pp. 202-206, 1985.